THE ENGINEER

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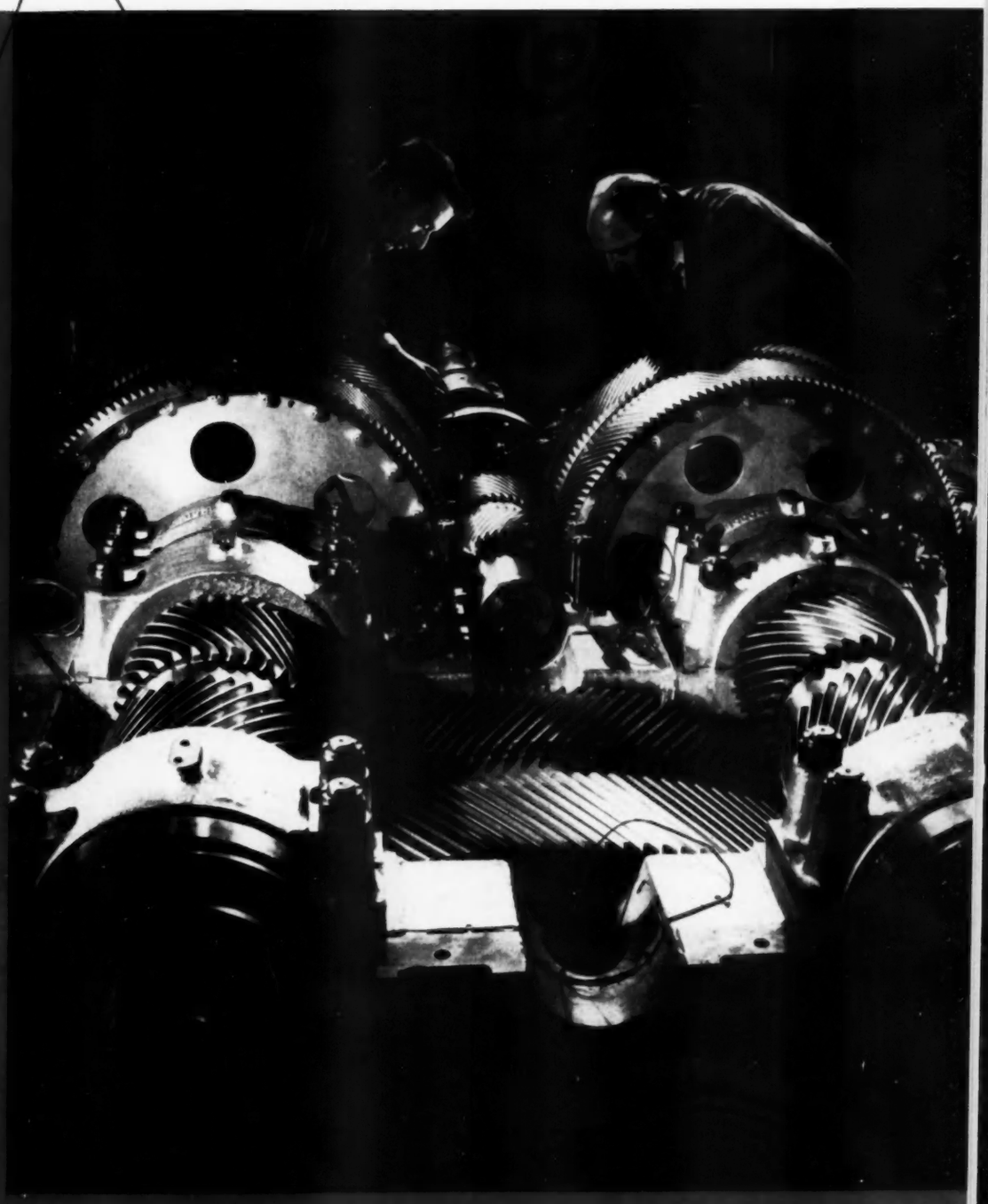

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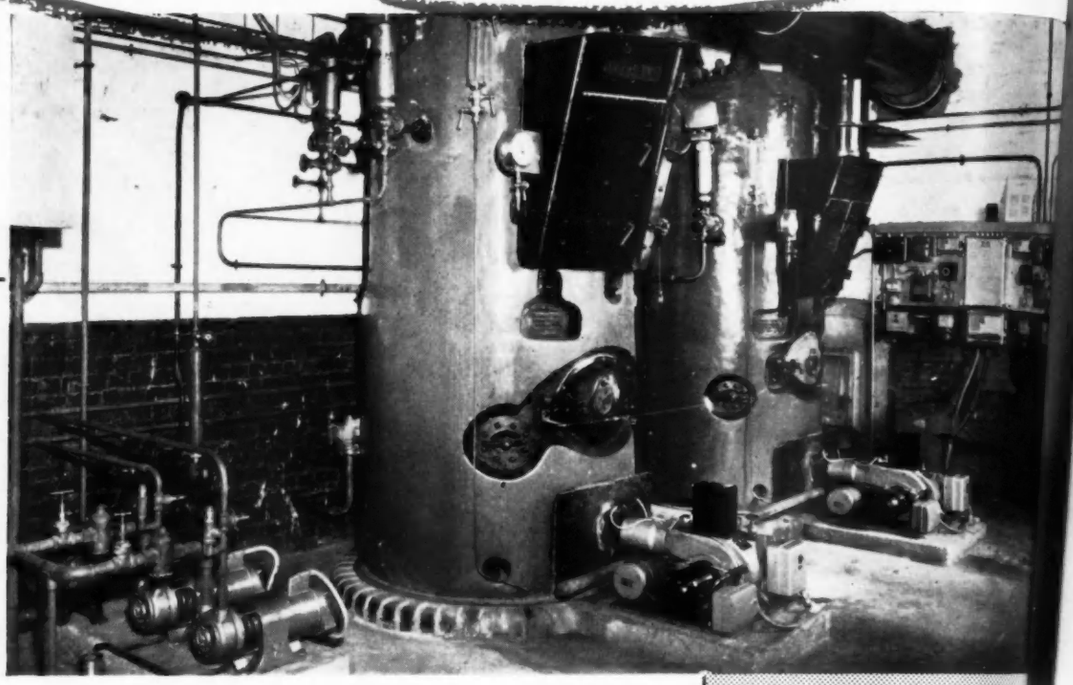

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Shell Smoke Number:		3.	4.
Boiler Efficiency (Gross C.V.)		77%	77%
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CO_2 content flue gas	Furnace:	11·5%	11·25%
	Boiler Exit:	9%	8·75%
Flue Gas Temperature	Boiler Exit:	450°F.	480°F.
Shell Smoke Number:		3.	3.
Boiler Efficiency (Gross C.V.)		73·5%	72%

NOTE: The drop in CO_2 content between furnace and boiler exit indicates leaks causing ingress of air.

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No. 5507 AUGUST 11, 1961 VOL. 212

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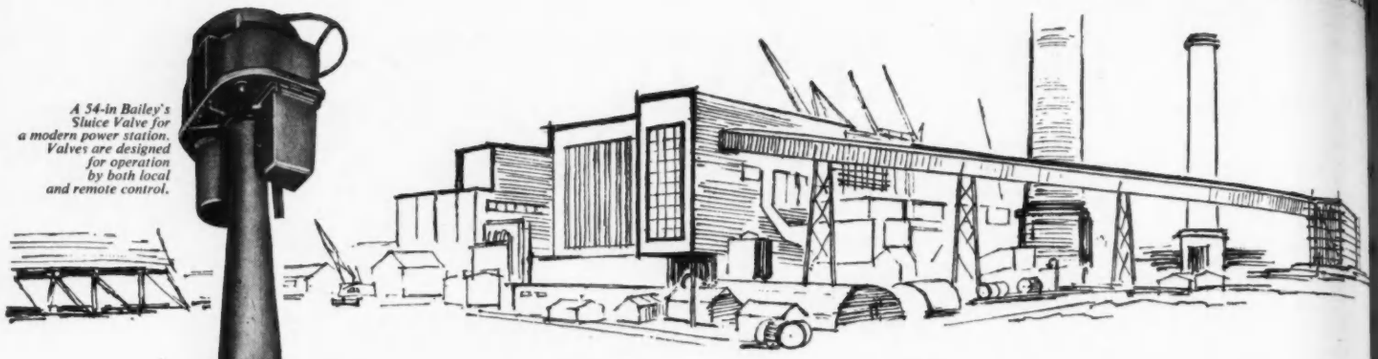

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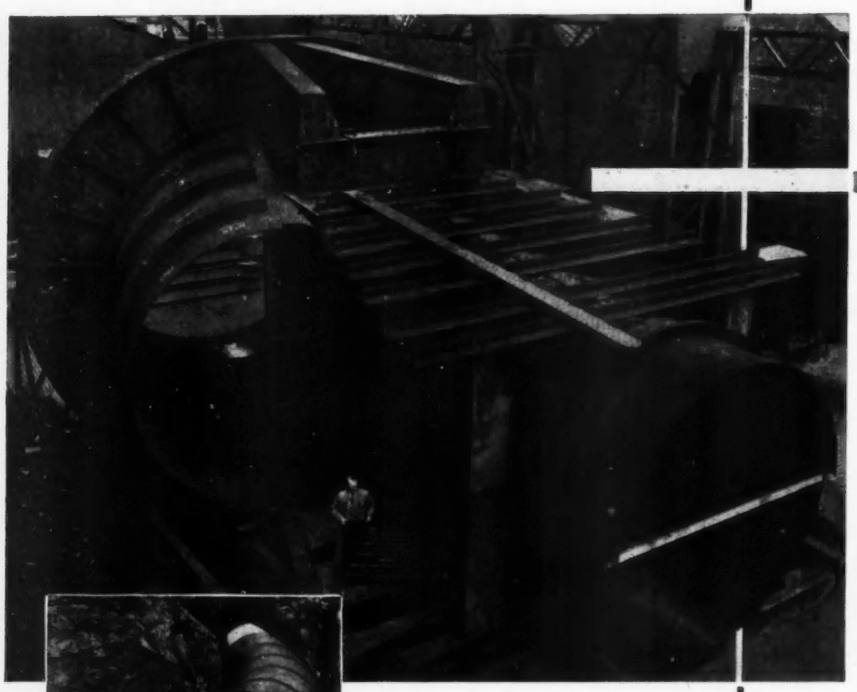

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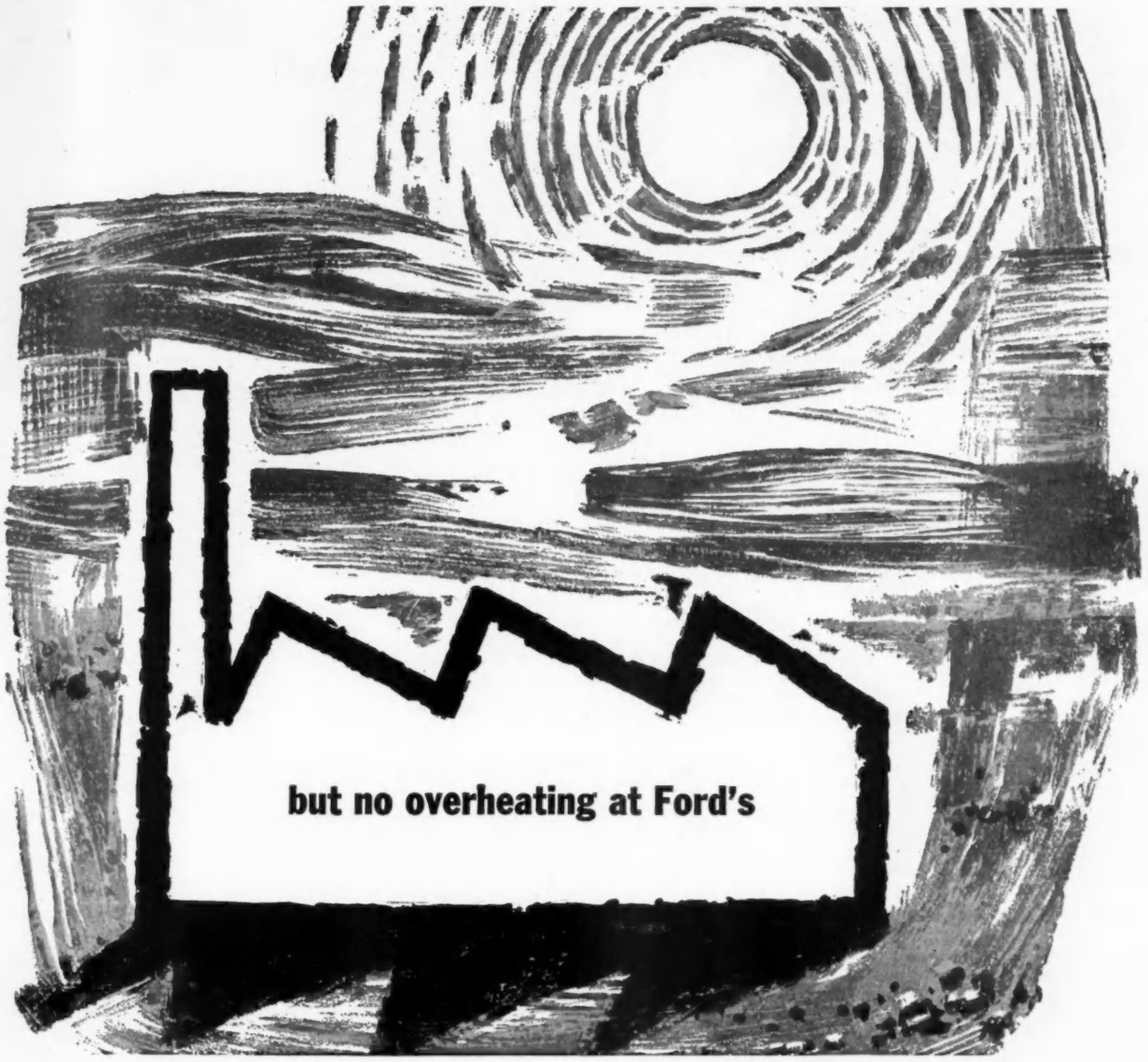

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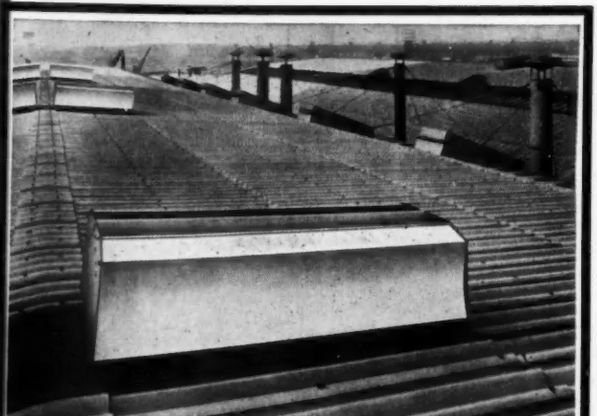

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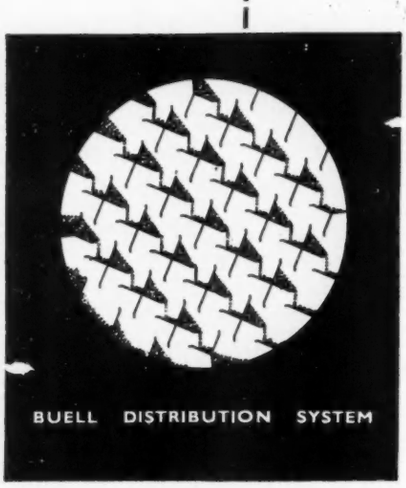

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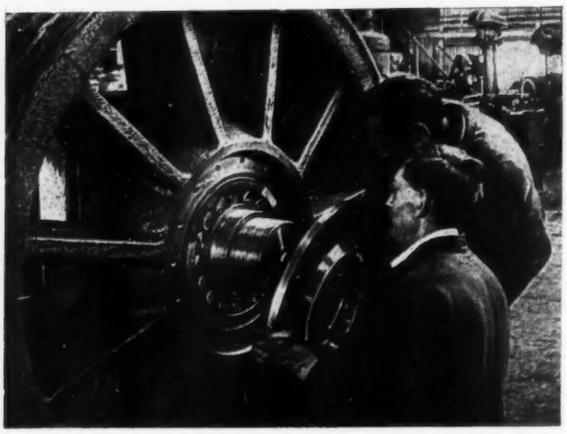

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THE ENGINEER

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MAN ORBITS AGAIN

There were rumours when Major Gagarin made the first orbital circuit of the earth in the spaceship "Vostok 1" on April 12 this year that in fact he did no such thing and that the whole affair was a gigantic hoax put on by the Russians to impress the world. The rumour never gained any support from scientists or rocket engineers in this country and since the events of last Monday it has lost all possible pretensions to be the truth. For there can be no possible doubts whatever that Major Titov did orbit seventeen times around the earth and landed safely on that day after spending twenty-five hours or so in space. The difference between the two operations is solely one of time for the orbits followed by the two spaceships "Vostok 1" and "Vostok 2" were almost identical. Gagarin's spaceship was in orbit only for a single circuit of the earth though no doubt it could have stayed in orbit longer. Human caution dictated that the first venturer into orbit should not be tried too highly; and that he should be brought quickly back to earth to report his sensations lest there be anything unforeseen about conditions beyond the earth's atmosphere or anything unbearable about the conditions of weightlessness. Gagarin paved the way for Titov. Similarly Titov has no doubt paved the way for someone to venture still further. What comes next?

Play is being made by commentators in Russia and elsewhere with the distance covered by "Vostok 2," some 435,000 miles, about as far as the moon and back. If the implication is that the spaceship, instead of circling the earth seventeen times, could have carried Titov to the moon and back it is not sound. To send the spaceship to the moon would have required its launching to be done by rockets capable of giving it almost twice the energy necessary for a close orbit around the earth. Furthermore a journey to the vicinity of the moon and back would take much longer than twenty five hours. How long, it thus becomes necessary to ask, can a man spend alone in a spaceship and in a state of weightlessness without suffering mental troubles, hallucinations, or physical or physiological effects of some kind? Before anyone dares to send off someone to have a close look at the surface of the moon men will have to demonstrate their ability to stand up to space vehicle conditions for a week or more. Titov demonstrated the feasibility of taking some kind of meal and of sleeping. Did he fall asleep naturally, one wonders, or was sleep induced by a drug? He is also reported to have "taken control" of "Vostok 2" on several occasions. Presumably, this means that he was able to orientate it in space from within. Such control is, of course, desirable if equipment such as a camera is to be used for photographing the earth's (or the moon's) surface. It is also necessary to orient the spaceship correctly before firing retro-rockets which cause it to re-enter the earth's atmosphere and return to the earth's surface. Possibly Titov had control over these retro-rockets as well; though one would expect that there would be over-riding control from the ground so as to ensure that in the event of a failure on his part to act correctly the vehicle and its occupant could still be brought safely back to earth. Only when it has been demonstrated beyond a peradventure that man suffers no ill-effects from prolonged orbiting, that he can take sufficient nourishment, that he can reliably perform tasks such as the correction of an orbit and the control of the orientation of the ship in space and, no doubt, that he can move about within a spaceship without difficulty and use instruments correctly, will it become sufficiently safe to authorise the projection of a man-carrying "Lunik" off the surface of the earth. If there are to be no casualties exploration of the possibilities must be done step by step. So far it is the Americans who have found themselves competitively behind the Russians. Thus when, within a very few months their next generation rockets, capable of doing all that present-day Russian rockets can do, become available, it is possible they may be tempted to venture too much too quickly in an endeavour to catch up in learning secrets which the Russians already know. It is, we suppose, useless to exclaim how very much better it would be if man's venture into space could be carried on co-operatively instead of in competition and under a cloud of secrecy about many of the findings.

THE KARIBA ABUTMENT

Announcement of further strengthening works for one of the abutments at Kariba dam has resulted in a somewhat apprehensive interest in the press, engendered, no doubt, by recollections of the Malpasset failure. There appears to be no reason for this attitude, and the consultant's statement, printed on page 243 herewith, is clearly quite logical and consistent. Doubts about the safety of large dams will continue to be felt here and there, however, until the final report on Malpasset is made public by the French. At present the legal proceedings require that it remain confidential, and the only technical assessment of the failure made public is that given in the preliminary report, published in THE ENGINEER, of May 13, 1960, by coincidence in the same issue as contained our article on the Kariba scheme. In that report, failure was attributed to a rupture of rock below the foundations of the dam. Increased attention has been paid, by engineers, since the Malpasset failure, to the behaviour of rock close to a dam and the recent congress on large dams held in Rome was noteworthy for the attention given to "rock mechanics" as this subject is now called.

It is possible that the rock mechanics of the Kariba site have been more intensively studied than would have been the case if there had been no disaster at Malpasset, for the French consultants have been concerned with both dams and presumably have an intimate knowledge

of the researches of the last two years at Malpasset. Whether or not this knowledge has affected the design of the strengthening works at Kariba only those responsible can say. But it needs stressing that the responsibility for a structure so vast and important as Kariba dam is so heavy, that any other consideration apart, the most rigorous measures to check the strength of the rock around it would inevitably be taken, and there is no reason to believe that the present works result from anything but an orderly and systematic engineering appraisal of the scheme, and its completion along the general lines originally conceived.

CANALS IN THE ECONOMY

The recent celebrations of the bi-centenary of the Bridgewater Canal, together with the organisation of THE ENGINEER editorial outing this August on the Grand Union Canal, have prompted in us some thoughts on inland waterways in general and on their use to-day in particular. At one time there were in Great Britain over 4,000 miles of inland waterways—canals and canalised rivers. A few, ill-conceived, were early failures and others have ceased to be navigable or have disappeared altogether, but some were phenomenally successful and about half the former mileage still remains open for traffic. Much of the surviving mileage is in the form of a cross, of which Birmingham is the centre and the routes to the Thames, Severn, Mersey and Humber are the arms. On the map this interconnection of some of the greatest manufacturing and shipping centres is ideal and in the past it was in fact so recognised and used accordingly. To-day, though here and there a length of waterway is busy, there are large sections where the passage of a working commercial boat is rare. So in some parts of the country there is the anomaly of ever-increasing traffic on roads which nobody pretends are adequate to carry it, and static or decreasing traffic on waterways serving the same destinations. It is easy to find reasons for the present underworked state of the waterways and easier still to find excuses. Many, though not all, of the reasons are now a matter of history. Neglect of some of the routes until they became unusable, deliberate stifling of traffic by some controlling bodies for reasons of their own; these are the principal historical causes of the dereliction or little-used state of some of the waterways.

But the fact remains that considerable lengths of waterway still exist, in navigable condition, and they must be kept in order and repair, if only as a means of water supply. It is not generally known that the canals of British Transport Waterways supply some 200,000 million gallons of water to industry annually. Two of the principal arguments against waterway transport are that it is slow, and that the costs of handling are high. Certainly it is slow; simple hydraulics limit the speed at which a boat can travel economically to little more than that of the plodding horse which formerly provided the motive power. But is speed so important? For some classes of goods, obviously it is; but fuel, sand, timber and a hundred and one other non-perishable commodities do not need to get anywhere in a hurry. What matters generally is that they shall arrive where and when they are needed. So long as a power station, for example, receives its fuel regularly and in the quantities required, it matters little whether the actual journey takes hours or days. If speed really is essential, what are the possibilities of the hovercraft on canals? Of goods handling, it need only be said that while it is clearly uneconomic to load and unload a boat manually, it is equally so to deal with lorry loads in the some way. Virtually, any form of mechanical handling from conveyors to cranes, from magnets to palletising, can be applied to boats just as well as to any other means of transport. Treat the waterway as just a route and the boat as simply a box, and the picture is clearer. Where a waterway exists between the points of loading and unloading the possibilities of floating the goods are worth investigating. Some ingenuity may be needed here and there, but it can pay in the end.

Finally, to consider one of the excuses as distinct from incontrovertible facts, it is a common plaint that even if the will to use waterways exists, the necessary labour does not. That may be true to a large extent, but it was even more true when canals were first cut. Nor were there people waiting around to drive the first railway engines or motor lorries, or to fly the first aircraft. They were found when they were needed. If one recognises the waterways as an asset, they should be used to the fullest economic extent. Otherwise it would be logical to scrap them and find other means of carrying out their present rather limited functions. If that were done it would destroy not only a potentially valuable asset, but one which has considerable amenity value as well. Some waterways have great aesthetic value, and pleasure boating and fishing are among their subsidiary but important uses.

EXPORT PERFORMANCE OF SMALL FIRMS

That the smaller firms play in the aggregate as important a rôle in the United Kingdom's industrial activities as the much larger and more complex organisations is not to be questioned. They perform many tasks more efficiently and more cheaply than could the relatively less flexible bigger organisations. Quite often in fact the smaller firm "feeds" larger ones which would be hard put to it to do without this help. When, however, note is taken of the smaller firms' efforts to sell their products overseas it has recently been suggested that less admiration should be bestowed upon them. According to the latest figures available from the Ministry of Labour there are more than 6000 engineering firms in Britain employing less than 100 workers; and, if the findings of an enquiry published last week by the Institute of Directors into just what are the factors inhibiting the expansion of export business can be taken as fairly representative, less than 18 per cent of these firms are vigorously interested in exporting their products. The study on which the report of the Institute is based was on a small scale; for the purposes of the enquiry a sample of only fifty-two medium, small and very small firms, having not more than 300 employees, not more than 99 and not more than 39, respectively, were interviewed. Half of them were manufacturers of consumer goods and half of engineering products but that distinction was found to have little if any significance. One major factor which emerged "beyond all possible doubt", the report states, was that in the overwhelming majority of cases, the failure of the British manufacturer to increase or even maintain his exports or to get into the export market at all, was a function not of any external circumstances, but of his general attitude towards exports. "It is not that he cannot export, but simply that he does not want to." In this connection, of course, the report adds, the phrase "does not want to" must be correctly understood. A genuine desire to increase the firm's volume of exports must necessarily

imply a willingness to take the appropriate steps to this end. The report goes on to say, however, that in practically no case was there found any evidence that a firm which really wanted to export would find any serious difficulty in doing so.

Study of the information given by these firms revealed that, so far as their export behaviour was concerned, they fell into four main groups. A quarter exported fairly vigorously; nearly half consisted of firms whose exports were either declining or static at a not very high level; a third group, a small one, was made up of firms which would like to export but did not know how to set about it; and the last group, slightly less than a quarter of all firms interviewed, did not export at all, had never done so, and spokesmen for these firms said they were not in the least interested in exporting, or, alternatively, expressed their interest "in such lukewarm terms as to make it clear that they were merely paying lip service to what has become an accepted political convention." The report points out, however, that this analysis is not quite as alarming as it might first seem. For firms having 100 to 300 employees showed a more re-assuring pattern than the smaller firms. Though there were fewer of them their greater output acted as compensation. Of all the reasons put forward by manufacturers for not exporting, and they were many and varied, perhaps the most significant, and short-sighted in view of a possible link with the European Common Market, is that a manufacturer able to sell his whole production on a buoyant home market has not any incentive to incur the extra work, worry and risks involved in selling abroad. It follows, we suppose, that were it made more obviously profitable to sell abroad than to sell in the home market (presumably through some governmental action) then more firms might be encouraged to take the trouble to find out how to set about exporting their products.

But we cannot feel very critical of small firms for not entering export markets on the basis of this report. For the facts and figures in the report take on a different aspect if seen in a different light. There is, for example, little information in the report about the ages of the firms concerned. But surely it is a very significant factor? The first task of a small and newly founded firm must be to establish sound and profitable roots and this can obviously be done much more easily in the home than in export markets. It is probably significant that a Table in the report shows that the proportion of firms exporting vigorously grows from a mere twelve per cent amongst very small firms to over 60 per cent for firms having 100 to 300 employees. Once a firm is securely rooted, those figures suggest, and it starts to expand, then interest in export prospects grows. Only 8 per cent of medium-sized firms proved to be wholly uninterested in exports (though 31 per cent were not very active in that field) as compared with 35 per cent of the very small. But the expansion of a very small firm may create growing pains. A managing director competent to run the affairs of a concern with only thirty employees may feel incompetent or actually be incompetent to run a business with 300. Is he wholly to be blamed if he decides not to attempt expansion? For if he does the consequence may be overwork and worry for himself or even his expulsion through the taking over of the firm by someone more competent to run it. It is, of course, desirable that small firms should expand and should export their products and they should be encouraged to do so. But no such duty is laid upon them. The country is a free one. Providing people accept the consequences for individual standards of living all are free to work as hard or not so hard as they like. Far from being disturbed by the figures in the report we think it remarkable evidence of vigour and competence that over 60 per cent of the medium-sized firms, a group into which we imagine a substantial proportion of smaller firms eventually tend to grow, are so active in exporting their products.

FIRE ! FIRE !

Time is often referred to as "the great healer," but time, or the passing of time together with its incumbent changes to a pattern of life that is familiar, may also open fresh wounds by relegating tried and trusted tools to a second class position in the order of things. Such a fate, alas, has befallen our old friend the fire bell. Indeed, it has fallen so far out of favour, that it now runs lamely along behind "a steady note siren," which according to the latest Fire Research Report, reviewed elsewhere in this issue, is itself only "a poor third" to a four-horn and a two-horn fire alarm system. Such is progress!

We shall mourn the now apparently inevitable passing away of the bell of the fire engine, for its strident clamour as the fire brigade weaves its way through knotted traffic is a sound which stirs the thinnest blood. Clanging bells and fires have been associated in our minds for long. We fear that if ever we hear a "four horn" system being used in the streets we may possibly confuse the engine with the now familiar ice cream van!

The Engineer—100 Years Ago (AUGUST 9, 1861.)

"A Clever Little Engine"

"On Wednesday we paid a visit to the wharf of Mr. A. Shipton, C.E., Wolverhampton, where that gentleman has at work a steam engine of novel construction, which he has just patented, and which is a modification of Mr. Shipton's engine shown at the Great Exhibition of 1851 . . . ." "The engine is of 25-horsepower, and works a cut-nail factory, a washer pressing works, saw mills etc. Although heavily loaded it seemed to do its work with great ease and economy. The space it occupies is about 4ft 6in by the same, and about 3ft 6in high. This limited space shows the engine to be, certainly in respect of size, admirably adapted to screw vessels. On the main shaft a cylinder is keyed eccentrically, and this works in a steam chamber suspended by a central bearing, in a beam resting on pillars attached to the bed plate, the top and bottom of the interior of the steam chamber is semicircular, and adjustable plates are fitted in the centre, which are in contact with the periphery of the cylinder. On the ends of the steam chamber are attached plates having holes through which the main shaft works clear. The admission of steam alternately top and bottom, of this eccentrically disposed cylinder, is by means of a slide valve, as in the ordinary engine ; and this cylinder is propelled up and down, and, during its propulsion, the shaft is caused to revolve. This plan is manifestly 'the most direct means of converting rectilinear into circular motion.' The engine is remarkably simple in its construction, and, no doubt, can be made very cheaply. Being self-contained it requires but light foundations."

Magnetic Tools*

By ALUN EDWARDS, Ph.D., F.I.M., F.Inst.P.†

Magnets as work-holding devices are of little use unless they can be switched and off at will, and it was the electromagnet which first provided this facility, though the permanent magnet was, of course, known very much earlier. In 1935 a permanent magnet chuck which could be switched off was made, and from this developed the very large range which is in common use in tool rooms and production shops to-day.

WILLIAM STURGEON was the first man to make an electromagnet with soft iron core winding, in 1823. He discovered the advantage of bending the core into horseshoe form to lift with both poles simultaneously, but he only used a single layer winding. It was the American, Joseph Henry, who, in 1829, wound the first coil as we know it to-day and was rewarded by the immortalisation of his name as the unit of inductance.

At the Great Exhibition of 1851 a giant electromagnet, reputed to be able to lift a ton, was exhibited, but this was only a scientific curiosity, as it had to be powered by batteries. The generation of electrical power on a large scale by rotating machinery was not to come for another twenty years. Although Faraday had succeeded in producing an electric current from a moving magnetic field in 1831, it was not until 1872 that Siemens and Halske designed something like a modern self-excited dynamo with a drum armature. The first commercial electric motor appeared in the following year. Thereafter the electrical industry started to develop.

By about 1899 steelmakers in Sheffield, and in the United States and Germany as well, were experimenting with lifting electromagnets to handle ingots, bars, plates and scrap in their stockyards. They had to build these magnets themselves; it was only later when their utility had been proved, that commercial manufacture of magnets started. The pioneers in Great Britain appear to have been the Sheffield firm of Steel, Peech and Tozer, with others not far behind.

In the United States, O. S. Walker, a designer for the Norton Emery Wheel Company, conceived the idea of using magnetic brake shoes on tramcar wheels. When the coil is energised the brake shoe clamps down on the wheel. This was technically successful but for various reasons was not adopted generally at the time. But Walker was not to be defeated. He turned his inventiveness to magnetic work-holding, that is the holding of iron and steel articles by magnetic forces instead of clamps, sufficiently firmly for them to be machined. There are two advantages in holding magnetically. First, time is saved in setting up as no clamping devices have to be found and adjusted. Second, clamps bend and distort thin workpieces and all kinds of expedients such as bedding in wax or holding down by adhesive were necessary.

The idea of magnetic workholding was not entirely new, but Walker improved on the existing design with his single coil chuck, the coil being completely protected by a substantial steel case, with a rectangular gap between the inner and outer poles. He soon realised that there was little hold on work that did not bridge a gap, and that it would be an improvement to extend the gap so that even small articles could bridge two or more gaps. This was patented in 1896 and in 1900 the O. S. Walker Company became the world's first manufacturer of successful electromagnetic chucks.

To-day many thousands of electromagnetic chucks are in use, but they have certain disadvantages. Heating causes distortion and inaccurate work and as it must be limited, an electromagnetic chuck cannot be worked at its maximum capacity. There is also the very considerable danger of parts being swept off the chuck by current failure. Possibly nothing more than a blown fuse may lead to serious accident. Furthermore the power supply must be direct current, and it used to be quite common to have to use a rotary converter with every chuck, costing as much as or more than the chuck itself, to change from a.c. to d.c.

One day about thirty years ago James Neill and Co. had a small circular slitting saw to face grind. Various ways of gripping this awkward shape were considered. "Why not try holding it on a loudspeaker magnet?" suggested someone. No sooner said than done, for at that time the main James Neill magnet business was making moving coil magnets. In a few minutes the job was completed, and there was no doubt that the permanent magnet was amply strong enough to hold the saw, so strong indeed that it was difficult to remove it after grinding, for permanent magnets by their very nature could not be switched off. Or could they? Was there some way of getting around this law of Nature? This was the question that Neill's chief designer, Mr. W. L. Bower, took home with him to ponder that night. No doubt it was not a new question; many others must have asked it and then dismissed it as impossible. But nobody had up till then produced a solution to it.

Mr. Bower found the answer. The law of Nature can be got around by providing a second magnetic path into which the flux can be directed, so that while the magnet maintains its full strength all the time it can be moved mechanically and its flux can at will and with very little effort be diverted out of the work and into the alternative path, thereby releasing or gripping the work as desired.

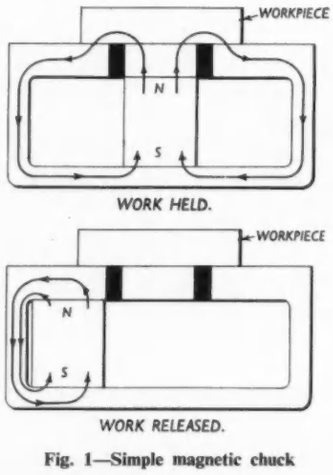


Fig. 1—Simple magnetic chuck

In essence, the idea is shown in Fig. 1. There is a top plate divided into three sections by non-magnetic gaps, with a magnet below the central section. The magnetic flux is constrained to pass through the workpiece and therefore holds it to the top plate. When the magnet is moved sideways, a much easier alternative path becomes available. Most of the flux follows this path, and the workpiece can be removed. In fact, however, with this simple design the flux diversion is insufficient for practical use. Mr. Bower's invention was much better than this. It is shown in Fig. 2. In this case there is a top plate which consists of a number of soft iron polepieces separated by non-magnetic spacers, a workpiece to be held, and a multipole magnet which could equally easily be a row of horseshoe magnets, capable of being moved along the under surface of the top plate. The short-circuiting now occurs in the polepieces themselves, and it is complete.

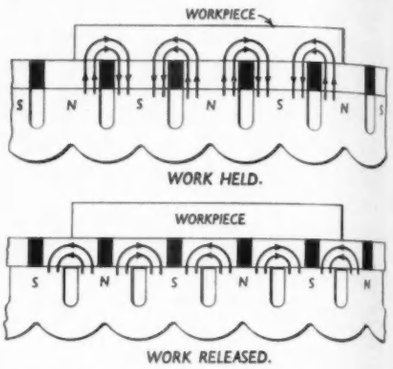


Fig. 2—Improved magnetic chuck with multiple pole pieces

It was hardly to be expected that anybody would believe that the chuck could keep its strength for long. On the contrary, it seemed natural that as everything ground on a chuck carries away some magnetism with it, the reservoir of energy would empty slowly until the chuck was useless. It is this fallacy that still makes people return chucks from time to time to be "recharged" as they put it. In fact, any magnetism taken away in a workpiece is fully accounted for by the work done in pulling it away from the chuck surface, and there is no limit to the number of times that mechanical energy can be converted into magnetic without weakening the chuck. Magnetism, like friendship, is multiplied by division. But these lofty sentiments were coldly received by the dealers. So before any chucks could be sold the doubters had to be convinced; this was done with a chuck that had been in regular daily use for two years, and showed no sign whatsoever of magnetic deterioration. Distributors received demonstration chucks with test plates for doubting customers to attempt to pull off. It was part of the drill for the representative to demonstrate with this test plate that the chuck surface was unmagnetised, then to turn the handle and lift the whole chuck clean out of its box by magnetic hold alone, which always made a tremendous impression.

The magnets in the original model were of cobalt steel. Although at the time it was made, nickel-aluminium magnets were just becoming available, the chuck makers feared their brittleness and played for safety; fortunately as it happened, for this proof of commercially successful cobalt steel chucks was most useful when rivals tried to prove magnetic chucks an obvious invention made possible by nickel-aluminium.

* The 1961 Celebrity Lecture to the Permanent Magnet Association. Abridged.

† James Neill and Co. (Sheffield), Ltd., Sheffield, 11.

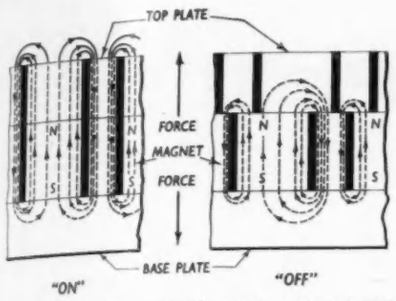


Fig. 3—Pack type magnetic chuck with balanced magnetic circuit

Many of the chucks sold in the first year gave yeoman service, and even now one is occasionally returned for repair. Recently one with a very low serial number arrived. It must have been sold in January or February, 1935. Strict instructions were given that it was on no account to be re-magnetised. It was carefully cleaned and relubricated, re-assembled, and reground. A record of the original test performance existed, and it was found that the chuck was slightly stronger than on the day that it was new. The performance of a chuck increases a little as the top plate is ground down in use ; this increase had more than balanced any deterioration of the magnets. The owners kindly investigated the history of the chuck. It was bought for use in their tool room, but during the war was pressed into service in production and was used both day and night for several years. Then it was returned to the tool room for less-frequent use.

After about a year the first model was discontinued and replaced by an improved version, making use of the new nickel aluminium magnets to give better holding area. The horseshoe-shaped magnets were replaced by a new form of magnetic pack (Fig. 3) built from alternate magnets and soft iron bars. The magnet is the broader unit because flux can be concentrated to a higher density in soft iron, improving the pull. The method of demagnetisation is obvious, but the baseplate is now part of the magnetic circuit. The pack is attracted to the top plate but it is also attracted to the baseplate. These opposing forces largely balance one another, so that frictional resistance to pack movement is small, a very useful help when moving a powerful chuck pack.

The initial distrust with which permanent magnet chucks had been received was beginning to fade, and at this stage Brown and Sharpe in the United States and Robert Bosch in Germany entered into agreements for the manufacture of chucks under licence. How, it may be asked, did the electromagnetic chuck manufacturers regard this invasion of their territory? Strange as it may seem, surprisingly favourably, as they excelled in the manufacture of large chucks, with which the permanent magnet chuck makers did not compete, and the small units were to them more trouble than they were worth.

Figs. 4 and 5 illustrate how magnetic flux is collected and diverted in the form of chuck with Alcomax magnets used to-day. All the magnets can co-operate and each delivers its share of flux to the workpiece. This is done by using a one-piece top plate so that flux from every magnet can pass around the edges and concentrate on the desired spot. This linking together of all the magnets in a common circuit averages out any difference between individual magnets and improves release in the " off " (Fig. 5) position when by movement of the pack the flux is diverted into alternative circuits.

There are many possible methods of flux diversion, but only some of them can also provide flux reversal. All the chuck constructions already mentioned, except the very

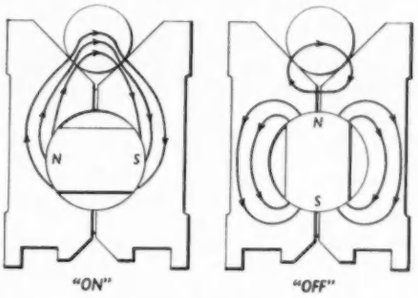


Fig. 6—Method of flux diversion in vee-block chuck

first, can do so, and Fig. 6 shows another method of switching off which is used in magnetic vee-blocks. Here a cylindrical magnet is used, magnetised across a diameter and rotatable between fixed polepieces. In the first position the workpiece, in this case a round bar, is firmly held in the vee groove. In the second picture the magnet has been rotated to the normal switch-off position and all the magnet flux is short-circuited in the polepieces, but if the work is hardened it holds itself to the vee-block by its own remanent permanent magnetism. This can be cancelled by rotating the magnet slightly beyond the neutral point.

The question a chuck salesman is most frequently asked, and a very natural question from the user's point of view, is the pull of a chuck in pounds per square inch? Fig. 7 shows a theoretical curve (which must be accepted with a lot of reservations), relating the pull density to the magnetic flux density

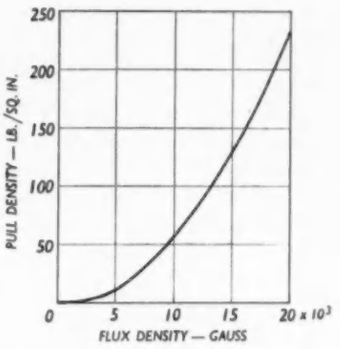


Fig. 7—Relationship of pull density to flux at contact surface

at the contact surface, and it will be seen that if the flux density can be forced up to 20,000 gauss, which is about the limit for soft iron, a pull of 230 lb per square inch can be achieved. This assumes that the work is held over its whole surface area, and it must be reduced by 15 per cent or so to allow for the white metal gaps between polepieces which are necessary if the chuck is to work at all. This gives a maximum of just under 200 lb per square inch. But it must be noted that the curve is not a straight line but a square law. Anything that reduces the working density has a profound effect on the hold.

There at least ten variables that influence the pull. They are the area, thickness, and material of the workpiece, the smoothness or otherwise of its surface, the state of its heat-treatment, its position on the chuck, the support it receives from other parts, the type of chuck, and the total loading. If the chuck makers are asked to specify the maximum cut that can be taken they must also consider the type of cutter, its speed, the direction of force that it exerts on the work, and the horsepower available to drive it. The apparently simple questions, " How great is the hold?" and " How deep a cut can I safely take?" are not to be answered glibly. In fact the manufacturers take a good deal of time machining customers' components in order to give factual answers to these questions. The actual components are necessary because the magnetising capacity of steel varies so much, and some kinds of stainless steel cannot be held at all. Examining components also reveals what some users think is a good flat surface. Poor contact is not now so serious as it used to be, but one might as well have the extra security so easily obtained by a little preliminary cleaning up of the workpiece.

It is of interest to consider what holding force is required to prevent the work from

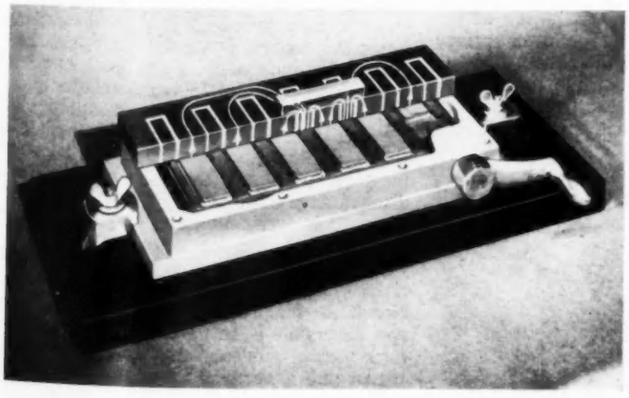


Fig. 4—Magnetic chuck showing path of flux in " hold " position

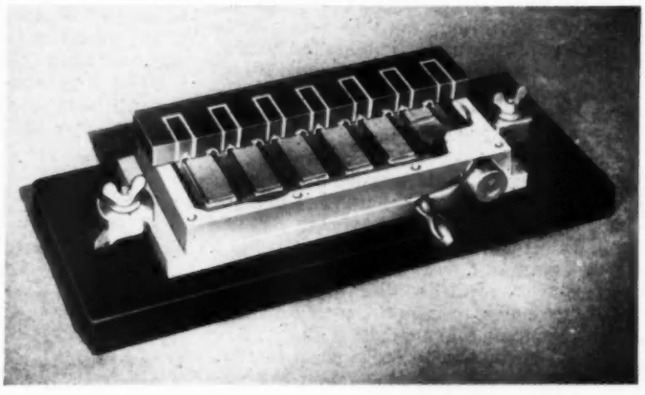


Fig. 5—Magnetic chuck showing path of flux in " off " position

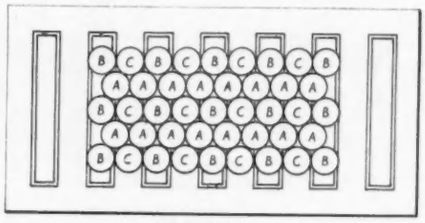


Fig. 8—Diagram showing holding power of a magnetic chuck on small objects

being moved by the cutter. If the surface speed of the cutter is V feet per minute and the force developed is F lb, then the horsepower exerted, which we should know, is $FV/33{,}000$. Take the practical case of a medium tool room grinder of 1 h.p. and a wheel speed of 6000ft per minute, the force to be resisted is only $5\frac{1}{2}$ lb. The faster the cutter the lower the force for a given power. This is the reason why magnetic chucks are so successful on grinding machines.

But it should be noted that the pull of the chuck is not F, but P, and if the work is prevented from sliding by its coefficient of friction alone, P needs to be four or five times F, and we need a pull of about 25 lb to provide a resistance to movement of $5\frac{1}{2}$ lb. This is so elementary that it hardly seems necessary to mention it, but every day work can be seen being machined, generally successfully, without any side or end support. The duty of a chuck is to hold work down, not to stop it from sliding. Support the work, which costs nothing, and give the chuck a chance to show what it can do.

Increasing confidence in the security of hold caused James Neill and Co. to start to supply permanent magnet lathe chucks in 1936, recommending for obvious reasons that they should be used for fast, light cuts. Electromagnetic lathe chucks had to receive their current through brushes and sliprings, which is all very well when the chuck is permanently built into the lathe, but inconvenient and dangerous when it is an accessory to be interchanged with jaw chucks and faceplates, which is the normal requirement. Permanent magnet lathe chucks were also welcomed because of the readiness with which work can be centred by partly switching on, so that the lightly-held component may be tapped into its correct position, and then locked by switching on fully and removing the control handle. What better means can there be of holding a thin disc for surfacing without distortion, or of rapidly finish machining a thin-walled cylinder?

A decision had to be made in these early days which was to have far-reaching effects on the future design of chucks. The chuck makers had to decide whether to design for a really powerful hold on thick work, or to give more attention to suitability for holding small and thin parts. This resolves itself into a choice of either coarse or fine pole pitching in the top plate. The decision was made that the majority of chucks should be designed for maximum hold under favourable conditions, that is, with massive workpieces, and that they should have coarse pole pitching which gives the maximum possible pull, as flux can then be driven deeply into a thick object and not be restricted to the surface layer. This had disadvantages when parts are small in relation to the pole pitching. Fig. 8 represents a number of discs to be ground. Neglecting the edge effect, that is, assuming that side and end support has been provided as always recommended, the discs can be divided into three classes, A, B and C, according to the hold the chuck can exert on them.

Class A is well held, each disc bridges one gap, and the area in contact with insert is the same as that in contact with top plate. The feed-return ratio is unity, which is ideal. Class B bridge two gaps, but contact is almost entirely with inserts, very little with top plate, the feed-return ratio is low and so is the pull. Class C do not bridge any gaps at all and are poorly held. Support from their neighbours prevents them from pushing off the chuck, but they may spin when the grinding wheel touches them. Because the diameters of these discs are half a pole pitch, the hold can be very good or very bad, depending on position. If the diameter is a whole pole pitch, the feed-return ratio is the same for any disc position. The pull is then more or less independent of position. If the length of the workpiece is less than three-quarters of a pole pitch, then there may be trouble.

Thin parts which are not necessarily small require fine pole spacing, but for a different reason. A thin sheet placed on a coarse pole spacing chuck is held down at each gap, but only with a small force because a small flux suffices to saturate the sheet. The only way of increasing the hold, therefore, is to have very many gaps, that is, fine pole pitching, the very reverse of what is desired for thick work.

Now by designing a powerful chuck with coarse pole pitching, it is possible to have the best of both worlds. The chuck as it stands can be used for heavy machining, and when required for small or thin work it can be temporarily transformed into a fine pitch chuck by an accessory known as an adaptor plate. This assembly of steel and brass bars divides the chuck flux into many parallel gaps, and it is a most useful addition. The point is that the transformation will not work the other way round ; it is not practicable to convert a fine pitch chuck, so there has been no reason to regret the choice so long ago.

Of course by no means all workpieces are so obliging as to have a conveniently large flat surface by which they may be gripped. How should one hold these components (Fig. 9), whose bases are curved? It is very easy, by turning the magnetic chuck into a magnetic vice. All that is required is two steel blocks, machined with ridges, one to contact the chuck inserts, the other to contact the top plate bridges. The blocks are pulled together by the flux passing through the sides of the workpieces, and grip them most securely.

Chuck blocks are another simple device. They are alternate steel and brass laminations held together by brass rivets. They are cheap and readily machined to any required shape, some of the flux appearing at the upper surface and holding the work to the block, some being active at the lower surface and holding the block to the chuck.

Often it is found worthwhile to machine the top plate of the chuck to conform to the contour of the part, and this when it can

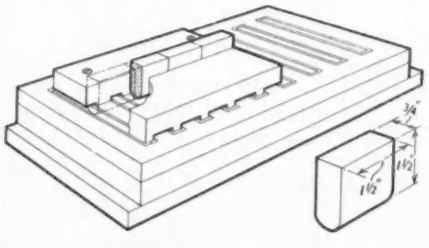


Fig. 9—Magnetic chuck adapted as a magnetic vice

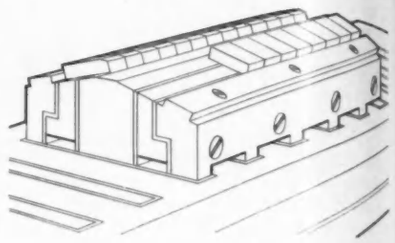


Fig. 10—Adaptor for bevel grinding

be allowed, gives the best hold of all. It is rather a drastic procedure, because the chuck is spoiled for general work. A very good alternative is to obtain several additional top plates, duplicates of the normal top plate, and machine each of them to suit a particular part. Then one chuck can be set up for any of these jobs by mounting the additional top plate, and the chuck itself is unimpaired for normal use.

There is no end to the types of special adaptors that can be constructed by the user for particular purposes. A typical one is shown in Fig. 10. It is a double straight-line adaptor for bevel grinding. Its construction is really quite simple, five soft iron polepieces and four brass spacers. Three of the polepieces have projections which contact all the top plate inserts ; the two others have projections contacting the top plate bridges. In this way flux is collected from the chuck and redispersed where it is required, across the straight-line gaps. These possibilities should be more widely known, for there is no doubt that when once a suitable adaptor has been built, an enormous amount of time may be saved on production operations of all kinds by eliminating setting-up and clamping. In fact the whole tendency in recent years has been for the demand for large chucks for production machines, as opposed to toolmaking, to increase.

During the past ten years ferrite magnets have become available, and more recently anisotropic ferrites. How should the new materials be used in magnetic tools? As is usual, the different magnetic properties of ferrites, the very high coercivity and low remanence and energy, require a complete rethinking of the design. One solution being used is shown in Fig. 11. There are two separate magnetic packs, one of which is part of the top plate. The magnets are slabs, magnetised through their thickness, that is, in a horizontal and not in a vertical direction. Alternate magnets are magnetised in opposite directions, so that not only are they thin, but they are placed together with poles opposing in a way that would severely weaken cast magnets. The ferrite by contrast thrives on this treatment, in fact this kind of punishment is necessary to make the ferrite show what it can do ; to drive its working point far enough down the demagnetisation curve for magnets, only $\frac{1}{4}$in long, to develop a creditable magnetomotive force. There is a tremendous flux concentration in the soft iron poles, each of which feeds into the workpiece the combined flux of four magnets. This is the way in which the disadvantage of the low working flux density of ferrite is overcome ; and one could hardly hope for a better illustration of the way in which an apparently quite unsuitable material can, by proper design of the magnetic circuit, be made to perform very well. The flux diversion is straightforward, the lower pack being moved along one pole pitch. Upper and lower packs then mutually short-circuit.

There being nothing without blemish in

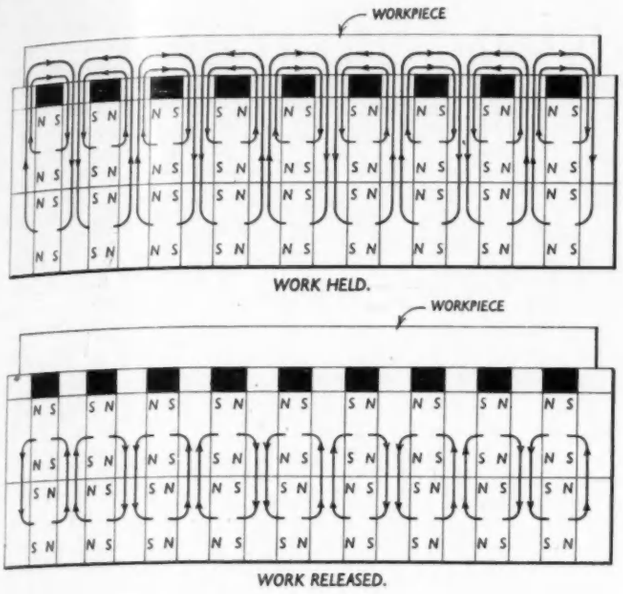


Fig. 11—Diagram of magnetic chuck using ferrite magnets

this world, ferrite chucks have their own peculiar merits and faults. To take the merits first, magnetic hold is quite good and is well maintained when the chuck is fully loaded. The hold on rough surfaces is satisfactory, and it is practicable to use closer pole pitching than is desirable with Alcomax alloy chucks. Release of soft iron parts is satisfactory, but this is not a reversing chuck, and there may be difficulty with hardened parts. Some reversal can be obtained by using longer magnets in the moving pack than in the fixed pack. There are many magnet blocks in a chuck and they are not cheap, so that at present it is an expensive construction—this is a situation that may change. Half of the magnets are in the top plate itself, which limits the amount of regrinding possible, and as the attraction to the moving pack is not balanced, but exerted on the upper surface only, it is mechanically difficult to switch on and off.

Even a normal magnetically balanced pack can be difficult to move when it is large and powerful, and so about seven years ago thought was given to an entirely new kind of chuck with no moving parts, a combination of the best features of permanent magnet and electromagnet chucks. Instead of demagnetising the chuck by moving the magnets, there are fixed magnets and coils through which currents are passed momentarily, just sufficient to demagnetise the magnets in position. Chucks of this kind can be made in large sizes. As the magnets are never moved there can be no mechanical difficulties in switching off, and as no clearance needs to be provided between magnets and top plate there can be no problem of deflection under load.

To remagnetise, a stronger pulse is passed through the coils in the reverse direction. As this pulse only lasts for two or three seconds the coil and rectifier can be grossly overloaded by normal standards, and as the coil therefore does not occupy much space there is room left for plenty of magnet alloy. The result is a chuck of unsurpassed holding power, with all the advantages of security, absence of heat distortion characteristic of permanent magnet chucks, and yet unlimited in size.

The practical difficulty in perfecting this kind of chuck was to develop a control circuit that would provide exactly the right demagnetising pulse, as an excess reverses the magnetisation and the chuck then fails to release. The problem is not so severe as might be imagined, because of the square-law relationship between flux density and hold. If the pulse is near enough to reduce the flux density in the work to 10 per cent of full value, then only 1 per cent of the hold remains, and release is easy. Moreover the strength of pulse is under the control of the operator, and can be adjusted to suit the work. These permanent-electro chucks, however, because of their associated control equipment, are only justified in large sizes, and for smaller units the principle of flux diversion is unchallenged.

As the result of many years' experience there has never been any reason to withdraw the guarantee that magnetic tools cannot lose their magnetism unless they are dismantled or mechanically damaged, but a few hints on their maintenance may not come amiss. Welding positioners in particular are subjected to very rough treatment, and are often suspected of being demagnetised when the trouble is due to nothing more than rough and pitted faces which can be completely cured by a regrind. The first advice is therefore to keep working surfaces in good condition. The second is to see that lubrication is maintained, and this applies particularly to chucks. If not done, the handle becomes stiff to operate, and in a bad case may seize up completely after several years of use. This is where trouble starts, for there is usually somebody in the shop who has just been waiting for the opportunity to see what is inside this rather mysterious box. He takes it into a corner and removes the baseplate. This breaks the magnetic circuit, and whether the mechanical trouble is rectified or not, the chuck will never be the same again magnetically unless it is returned to the maker for remagnetisation. The maker's analysis of service records shows that about half the chucks returned for overhaul have been opened.

There are now many companies both in Britain and abroad making magnetic tools using the Bower flux diversion principle, and James Neill and Co., the original maker, has increased its manufacturing capacity several times. But there appears to be no end in sight to the development of the principle which was first introduced by Mr. Bower in 1933, and has been adapted and improved by him ever since.

A Locomotive History—The "Atlantic"

By E. C. POULTNEY, O.B.E.

No. III—(*Continued from page* 138, *August* 4)

The London, Brighton and South Coast Railway "Atlantic" Type Locomotives

Considering the remaining engines built for British railways in the order of their appearance, those designed by D. E. Marsh in 1905 for the Brighton line next claim attention. In design, these locomotives were almost an exact reproduction of H. A. Ivatt's Great Northern locomotives of the 251 class; in fact, they could very well have been built from the same drawings and probably were, at any rate to a large extent. Their designer having been in charge of the Doncaster Works under Ivatt was fully conversant with the Great Northern "Atlantics," and after his appointment as Locomotive Superintendent of the Brighton line the Doncaster design was chosen when locomotives of enhanced power were deemed necessary for main line passenger traffic. From the dimensions given by the table and from the accompanying illustration (Fig. 23), the likeness of the two different engines will be appreciated, though certain dimensions differ, notably the size of the cylinders, and the working steam pressure was higher.

The rated tractive force is 19,200 lb, so that with 37·75 tons on the coupled wheels the adhesion factor is 4·38. The wide firebox boiler is practically identical with the Ivatt design, though, as will be noted from the particulars given in Table IV, the Marsh engines had slightly less heating surface.

Table IV—*British "Atlantic" Type Locomotives Period* 1898–1906

Column number	1	2	3	4	5	6	7	8
Date	1898	1902–10	1903	1904	1904–10	1904–5	1905–11	1906–21
Railway	G.N.R.	G.N.R.	N.E.R.	G.C.R.	N.E.R.	G.W.R.	L.B. & S.C.R.	N.B.R.
Cylinders, diameter and stroke, in	18½ × 24	18½ × 24	20 × 28	19 × 26	20 × 28	18 × 30	18½ × 26	20 × 26
Driving wheels, diameter, in	79½	79½	82	81	82	80½	79½	81
Steam pressure, lb per square inch	175	175	200	180	175	225	200	200
Tractive force, lb	15,790	15,790	23,300	17,729	20,350	23,090	19,200	23,500
Total heating surface, square feet	1439	2500	2455	1972	2249·5	2142·9	2473·5	2256·2
Grate area, square feet	24·5	30·9	27	26·2	26·63	27·09	31·0	28·5
Weight on driving wheels, tons	32·75	36	39	37	40·2	39·0	37·75	40
Engine weight, tons	60·0	68·4	72	71	76·2	70·5	67·0	74·4
Factor of adhesion	4·15	5·1	3·75	4·67	4·42	3·76	4·36	3·92
Figure number	14	16	18	21	19	22	24	25

N.E.R. locomotives Column 5 as first built used saturated steam and had 19½in cylinders. Dimensions given apply to those built later. Heating surfaces include superheater surface.

Dimensions of all other locomotives are as first built without superheaters.

G.N.R. Locomotives Columns 1 and 2. Diameter of driving wheels later increased to 80in with tyres modified in diameter over flanges to suit the standard wheel spacing of 6ft. 10in

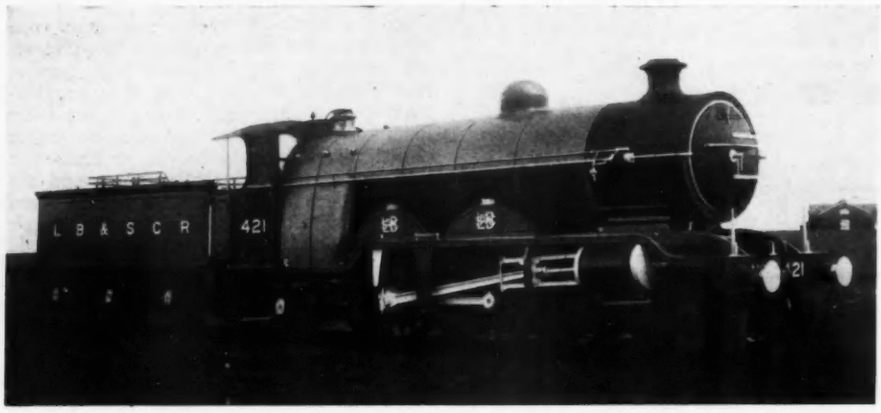


Fig. 23—"Atlantic" type locomotive for the Brighton line—D. E. Marsh: first built 1906, superheated 1911

Later, in 1911, a further lot of these engines were placed in traffic, differing from the original in certain respects, notably by being fitted with superheaters and enlarged cylinders of improved design. The working steam pressure was reduced to 170 lb per square inch and the new boilers of the same dimensions as the original had revised heating surfaces, which totalled 2491·7 square feet, made up by 1895 square feet contributed by the tubes and flues, 136·47 square feet in the firebox and 460 square feet given by the superheater having twenty-four sets of elements. As thus built, the engine only weight became 68·25 tons, of which 37·25 were on the coupled wheels. With larger 21in by 26in cylinders, together with steam at a pressure of 170 lb per square inch and driving wheels of the original size, 79½in, the tractive force, maximum, was 20,900 lb, giving an adhesive factor of 4·0. The photograph reproduced shows one of the later engines fitted with larger cylinders and superheater. In other respects, these later engines did not differ from the original.

The North British "Atlantics"

The last "Atlantic" type locomotives to be designed for a British railway were built in 1906 for the North British Railway from the designs of W. P. Reid, Locomotive Superintendent. Built by the North British Locomotive Company, (Fig. 24), they were large engines, being, in fact, the heaviest in Britain at that time. The engine only weight was 74·4 tons, compared with 72 tons for the Worsdell "Atlantics" of 1903 for the North Eastern Railway, which, in point of fact, the new engines closely resembled. This will at once be noticed if the particulars given relating to these engines in Table IV are compared.

The noteworthy difference between these locomotives is the Belpaire type of boiler adopted for the North British. These large engines were a great advance in power compared with any previously built for the North British line, which had hitherto relied on 4–4–0 type engines, which had gradually been developed in power by M. Holmes, the previous Locomotive Superintendent, and had, moreover, done good work on a difficult road for many years.

Before the "Atlantic" was finally decided upon as a means of providing additional motive power to work heavy passenger traffic over a difficult road, consideration was given to the six-coupled type; however, ultimately it was decided that an "Atlantic" would be more suitable, largely, the writer understands, on account of the sinuous character of the line between Carlisle and Edinburgh (Waverley). The design was prepared by W. P. Reid, Locomotive Superintendent at the Cowlairs Works, Glasgow, and first built, as already stated, by the North British Locomotive Company in 1906. In general design and in many respects in their proportions, these large engines assimilated W. Worsdell's North Eastern engines of 1903. The cylinders were of the same size, as were also the 10in piston valves, operated, moreover, in the same manner by Stephenson's valve gear.

So far as the boilers are concerned, while the Cowlairs engines had Belpaire fireboxes, they were otherwise generally very similar to those of the Worsdell engines. The total heating surface of 2256 square feet compared with 2455 square feet of the Worsdell design. In some respects, these North British "Atlantics" were notable examples of the type, and represented a handsome appearance. In service they have been said to have been rather heavy in coal consumption. This is, however, understood to have been corrected to some extent when, later, superheaters were fitted. The leading dimensions given in Table IV apply to the locomotives as built without superheaters. Supplementary particulars after the fitting of superheaters are given as follows :

Cylinders, diameter and stroke, in...	21by 28
Heating surfaces, square feet :	
Tubes and flues	1619
Firebox...	185
Superheater	385
Total	2189
Grate area, square feet	28·5
Tractive force, maximum, lb... ...	23,325
Weight, tons :	
On drivers	40
Engine total...	76·75
Factor of adhesion	3·85

Indian Railways—Standards

Any account of British practice could hardly be said to be complete without a brief reference to the well-known and largely successful Indian standard designs, formulated during the early years of the present century by the British Engineers Standards Association (B.E.S.A.). There is no need to go into this in detail, but it is quite in order to recall that the second report dealing more specifically with locomotives of the larger types for the 5ft 6in gauge lines described, amongst others, two designs for heavy passenger traffic. These were of the 4–6–0 and 4–4–2 types. Large numbers of the former were built during the succeeding twenty years or more, and there were also some of the 4–4–2 engines, true "Atlantics," some of which the writer can recall were built by the North British Locomotive Company for the Great Indian Peninsula which were for all practical purposes in accord with the approved standard design; and in 1908 some "Atlantics" were built by The Vulcan Foundry for the East Indian Railway; these were, however, somewhat different from the B.E.S.A. proposals.

The specified requirements covering passenger engines of the 4–4–2 "Atlantic" type for the broad gauge lines were as follows :

Cylinders, diameter and stroke, in ...	19½ by 26
Coupled wheels, diameter, in	78
Weights :	
Engine (working order), tons	67·2
On driving wheels	35·0

Both the 4–6–0 and 4–4–2 type were subject to other requirements as under : Boiler pressure 180 lb per square inch. Total heating surfaces not to be less than 2000 square feet. Grate area not to be less than 30 square feet.

The accompanying illustration (Fig. 25) kindly supplied for this article by the North British Locomotive Company, shows the standard "Atlantic" design built for the Great Indian Peninsula Railway. These engines complied in all the principal dimensions with the standard requirements, differing only in certain details which conformed with existing practice on the railway.

The undermentioned are the leading dimensions of these locomotives :

Cylinders, diameter and stroke, in ...	19½ by 26
Coupled wheels, diameter, in	78
Boiler steam pressure, lb per square inch	180
Rated tractive force, lb	19,490
Heating surfaces, square feet :	
Tubes	1880
Firebox...	157
Total...	2037
Grate area, square feet	32
Weight, tons :	
On coupled wheels	31·45
Engine, total	66·70
Tender	60·26

The tractive force given is based on the factor 0·85 for the mean effective steam pressure, maximum, referred to the rims of the drivers. The factor of adhesion is 3·97. The design of the cylinders and valve chests was generally in accordance with practice common at that period, the latter being between the frames with ordinary slide valves driven direct by Stephenson's valve gear.

A Transgression

In concluding these notes on the development of the "Atlantic" type, a transgression will be made by introducing as a final example of the 4–4–2 type a locomotive design, though not a true "Atlantic", which has an irresistible claim for inclusion in this review of a locomotive type which has, in

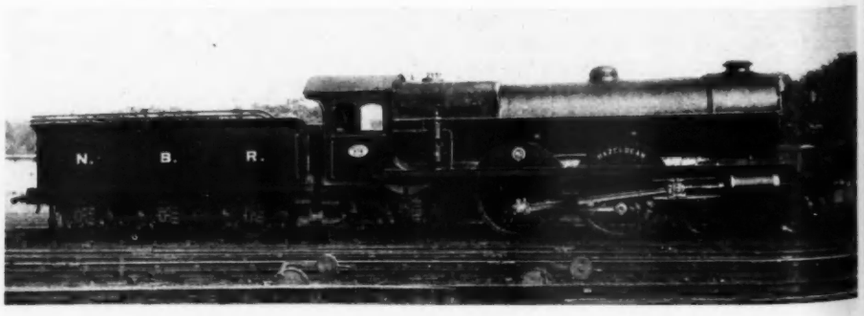


Fig. 24—Reid's "Atlantic" design of 1906 for the North British Railways

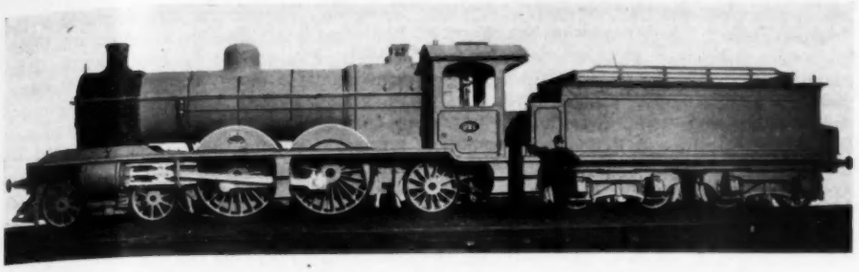


Fig. 25—Indian Railways " Atlantic " as built for the Great Indian Peninsula Railway

the writer's view, influenced locomotive design practice to a greater extent than any other during its life, extending over some 150 years. The locomotives to which attention is now drawn are represented by the photograph reproduced in Fig. 28. Claim for attention is substantiated for certain well-defined reasons. It has the 4–4–2 wheel classification. It was designed specially for high speed passenger service on the Chicago, Milwaukee and St. Paul and Pacific Railway, and it represents the final example of a four-coupled type to be built for any railway to operate important main line services. As a design, it can claim to be a direct development of the original " Atlantic " of 1894, reintroduced in a modified form in 1935. Such claims could not, it is thought, be fairly resisted, and are now put forward as an apology for what may be termed a transgression, freely admitted.

When writing on the Baldwin compound " Atlantics " of 1896, it was explained that the Milwaukee at that period desired to improve certain passenger services operating between Chicago and Milwaukee. These later engines were also introduced for similar reasons, though rather more extended. Before dealing more specifically with these engines, what they were intended to do may be briefly mentioned. In the early part of 1935 the Milwaukee placed in service a new train, the " Hiawatha," operating between Chicago and the Twin Cities of St. Paul and Minneapolis ; the distance from Chicago to St. Paul is 411½ miles over the Westbound tracks, and, Eastbound, the distance is rather less, 410½ miles. Between St. Paul and Minneapolis running speeds are much restricted ; therefore, high speed working is confined to the Chicago–St. Paul section, part of which comprises the 85 miles between Chicago and Milwaukee. The time allowed, including seven stops, was 6½ hours for the distance between Chicago and St. Paul with trains of 450 tons or more, and the time allowed, non-stop, from Chicago to Milwaukee was seventy-five minutes for the eighty-five miles, representing an average speed of sixty-eight m.p.h.

In practice, point to point timings are given as being 90 and 96·6 m.p.h., and actual maximum speeds regularly recorded vary from 100 to about 106 m.p.h. When first put into service, the " Hiawatha " was the fastest and, indeed, the only steam-hauled train in the world regularly calling for speeds of 100 m.p.h. The original trains were made up of six cars weighing 313 tons, but these were later replaced by nine-car sets having a weight of 430 tons, which these 4–4–2 type locomotives handled without any difficulty. It was to meet these exacting requirements that the American Locomotive Company, in conjunction with the Milwaukee motive power authorities, worked out the design of these four-coupled locomotives, which exceed in capacity any others ever built with the 4–4–2 wheel arrangement. The following are the principal dimensions of these locomotives :

Milwaukee 4–4–2 *Locomotives*

Cylinders (two), diameter and stroke, in	19 by 28
Piston valves, diameter, in	10
Coupled wheels, diameter, in	84
Boiler steam pressure, lb per square inch	300
Heating surfaces, square feet :	
Tubes and flues	2951
Firebox	254
Firebox syphons	40
Evaporative total	3245
Superheater, type " A "	1029
Combined	4274
Grate area, square feet	69·0
Rated tractive force, lb	30,685
Weight, tons :	
On driving wheels	62·5
Total engine	125·5
Tender, loaded	110·5
Total locomotive	236·0
Tender, water capacity, gallons	13,000
Tender, fuel oil, gallons	4000

Oil fuel was used on account of the high ash content of the Indiana coal normally used by the Milwaukee and the desire to make the through run of 410 miles between Chicago and St. Paul, the brief stops not allowing for time for cleaning ashpans. From the dimensions given, the large size of the boiler and the high working steam pressure will attract notice.

In this connection, it may be pointed out that the grate area of 69 square feet is the equivalent value. Actually, there is no grate, as such, with oil firing. The weight on the coupled wheels of 62·5 tons is a further point worthy of note, especially when compared with the 31·3 tons allowed for the Baldwin compounds of 1896. Further, as having a bearing on the remarks made regarding train resistances when discussing the Baldwin engines, it may be said that the rails now laid in the track weigh 131 lb per yard as a maximum for the latest rail section. Some lengths, however, had rails rather lighter at 110 and 120 lb per yard.

The 19in by 28in cylinders complete with valve chambers are cast integral with the cast steel engine frames and have 10in piston valves receiving a 6½in full gear travel from Walschaerts gear. The steam lap is 1⅛in, lead ¼in and there is an exhaust clearance of ¼in. On account of the high speeds required to work the services, the diameter of the coupled wheels is 84in, and for the same reason special attention was given to the design of the motion, particularly the reciprocating masses, which have a total weight of 1003 lb on each side of the engine. With one-third of the reciprocating parts balanced, the dynamatic augment at a running speed of 100 m.p.h. is given as being 10,800 lb, or 4·8 tons. The total weight of the locomotive is 527,000 lb, so that the underbalance of 672 lb gives a locomotive weight underbalance ratio of 785 to 1. The transverse distance between cylinder centres is 78in.

The material used for the connecting and coupling rods is high tensile nickel steel ; they are of channel section, the latter being fish bellied to obtain the required stiffness.

With steam at 300 lb per square inch pressure, the maximum piston load amounts to 85,200 lb, but, as the connecting and coupling rods are of the tandem pattern, this load is divided between the main and the coupling rod pins in the trailing wheel centres.

In addition, this method of construction reduces the loadings between the axleboxes, and the attendant guides tend materially to reduce wear at these points. Floating bushes are applied at all crank pins, which are of carbon steel, hollow-bored. The driving wheels have Boxpok centres mounted on hollow axles and journal boxes of the S.K.F. pattern. The leading truck is of the Commonwealth four-wheeled type with inside journals. The trailing truck is of the Commonwealth Delta type with hollow axles and the American Steel Foundries roller bearing axle assembly fitted with Timken roller bearings.

The brake gear is compensated throughout ; clasp brakes are applied to all wheels of the engine and tender. Two cylinders are fitted to the leading four-wheeled truck and to steady the frame against the tilting action of the brake blocks when a brake application is made the ends of the equalisers are extended beyond their bearings on the journal boxes to support the seats for coiled cushioning springs under the four corners of the truck framing. Based on a brake cylinder air pressure of 50 lb per square inch, the braking ratios are engine leading truck 45 per cent, trailing truck 60 per cent and driving wheels 78 per cent.

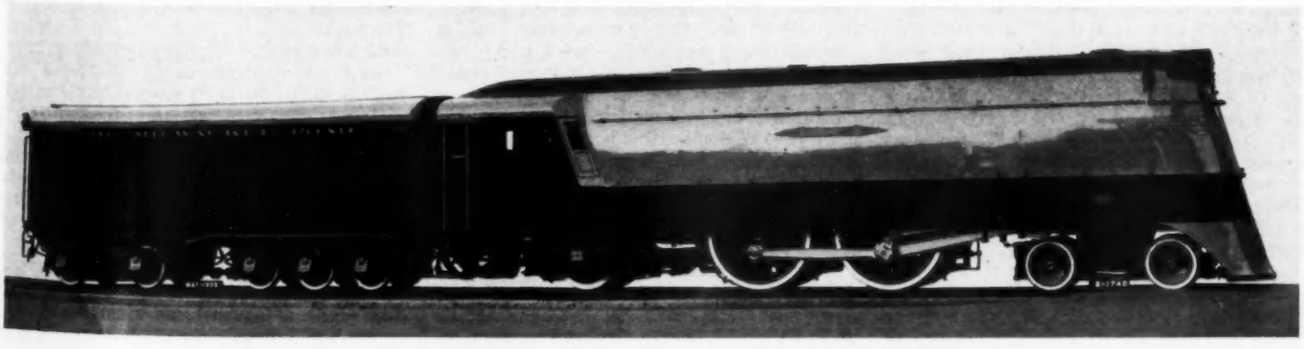


Fig. 26—High speed 4–4–2 locomotive. C. M. & St. P. & P. R., 1935

Concluding Remarks

The foregoing account of the evolution of the " Atlantic " for main line fast passenger requirements attempts to outline the development of a locomotive type introduced, in the first instance, as a development of the celebrated engine " Columbia " with the 2–4–2 wheel arrangement of 1893. As a locomotive type, the " Atlantic " had a comparatively short life but was, even so, notable as being the forerunner of all modern high-powered steam locomotives. From its inception in 1894 up to about 1914, it enjoyed a considerable measure of attention and established a reputation in high speed passenger traffic, especially in North America where its advantages were recognised, and the possibilities offered by the wheel arrangement fully exploited. In British practice, while the examples put into traffic were generally successful, it is, nevertheless, true that only H. A. Ivatt recognised the true meaning of the " Atlantic." The first engine of 1898 proved the value of the type, and the design of 1902 with its large boiler and wide firebox showed that the designer fully realised the advantages offered by the wheel arrangement. It is for this reason that the Ivatt " Atlantics " rank high in the annals of the history of British locomotive practice.

H. A. Ivatt at Doncaster and W. Worsdell of the North Eastern both designed their express locomotives as " Atlantics " by making full use of the 4–4–2 wheel plan, the former by adopting a wide firebox and the latter by designing an excellent boiler with a deep firebox of the more conventional narrow pattern.

Marsh at Brighton copied Ivatt's engine and Reid of the North British took Worsdell's engines as his model. The other " Atlantics " for the Great Central and Great Western, though excellent engines, were, nevertheless, somewhat handicapped by having boilers designed for a 4–6–0 type design.

What these two designs did was to prove that four-coupled engines, given equal boiler and cylinder power, could do work equal to that performed by a six-coupled engine having the same tractive effort at a given speed. It is true that the Great Western " Atlantics " were ultimately converted to the 4–6–0 type, thus demonstrating the fact that changing the trailing pair of coupled wheels of a 4–6–0 design and substituting for these a pair of smaller carrying wheels will not necessarily provide a successful 4–4–2 engine. Further, it prevents the primary advantage offered by the " Atlantic " being fully realised.

To be a true " Atlantic " calls for a design both in the wheel arrangement, the position of the cylinders and the method of effecting the drive to the coupled wheels, as portrayed by the Baldwin engine of 1894.

For this reason, the Milwaukee locomotives are not true " Atlantics " ; however, the writer believes their inclusion in this review of the development of the " Atlantic " may be acceptable. As a design, they were undoubtedly outstanding, not only being the last of the four-coupled type to be built for important main line passenger services, but were also the most powerful and most modern examples of high speed steam motive power then in existence. In some fairly obvious respects they could now probably be improved, though it is doubtful if the energy required is now available. However, they constitute a design of considerable interest and, as such, merit, it is thought, inclusion in this historic account of the development of the " Atlantic " as seen in North America and on British railways.

Acknowledgments

In conclusion, the writer wishes to acknowledge the assistance received from many friends in preparing this review of the development of the " Atlantic " locomotive.

Thanks are due to R. Arbuthnott, North British Locomotive Company ; B. Spencer, late of the C.M.E. Department, Eastern Region, B.R. ; also to M. G. Burrows, C.M.E. and E.E., North Eastern Region, B.R. ; R. A. Smeddle, C.M.E. and E.E., Western Region, B.R. ; and C. R. H. Simpson. Thanks are also accorded to the Baldwin-Lima-Hamilton Corporation, Philadelphia, Pa., and to L. E. Gingerich, Chief Mechanical Officer, Pennsylvania Railway, Philadelphia, Pa., U.S.A. The old prints of locomotives built by the American Locomotive Company have been furnished by the City Archivist, Schenectady, N.Y., U.S.A., the custodian of the American Locomotive Company's photographic negatives of steam locomotives. Thanks are due for this service.

Shaft Sinking at Kellingley Colliery

The National Coal Board is developing a new colliery at Kellingley in the Castleford area of the North Eastern Division. Two 24ft diameter shafts are being sunk to a depth of about 850 yards, and high rates of sinking have been maintained. The coal measures are overlain by 600ft of water-bearing Permian rocks, and in this zone the freezing process has been utilised.

HIGH rates of sinking have characterised the shaft sinking operations at Kellingley. The shaft-sinking is being done by the Thyssen Shaft Sinking Company, Ltd., the freezing process being the responsibility of the Foraky Company, Ltd. Last January, in unfrozen ground, 336ft were sunk and 345ft lined in No. 2 shaft. Sinking and lining are non-simultaneous.

The main sinking of No. 1 shaft started on February 26, 1960, and No. 2 shaft on June 19, 1960. Each shaft is served by two tower-mounted friction winders, and these are being used for the sinking operation. After shaft sinking has been completed the winders will be fitted with closed loop-control and it is proposed to wind the output at No. 2 (upcast) shaft in 15-ton capacity skips ; No. 1 (downcast) shaft will be equipped with two three-deck cages and be used for winding men, materials, and dirt.

Equipment for Sinking

The main equipment used for the sinking consists of a two deck stage suspended in the shaft by four ropes which also act as guide ropes for the riders of the hoppits. The decks are 30ft apart and surmounted by a catwalk 10ft above the top deck. The first or upper deck carries four 2-ton winches for movement of the shuttering in the shaft, and between the decks is located the octopus and chutes for emplacing the concrete lining. Underneath the bottom deck of the sinking stage is the compressed-air-driven mechanical loading equipment which is suspended from an inner and outer monorail. The main hoist motor, which operates the 20 cubic feet Priestman "Cactus" grab, is also mounted on rails inside the unit, which then allows the grab transverse as well as circumferential movement. The drilling hoppit consists essentially of a number of radial steel sheet plates which form segments to which the drilling machines are returned after use. The mucking hoppits—in No. 1 shaft, 85 cubic feet, and No. 2 shaft, 105 cubic feet capacity—are secured to the winding rope by three suspension chains, the chains being detachable from the hoppits to leave them clear for loading.

To provide the required high rate of production, coupled with a consistent mix, there was installed a Blaw-Knox AP.100 concrete plant which has an output of 100 cubic yards per hour arranged to feed to either shaft. Essentially this plant consists of four sections, the first of which is an eight-compartment batching plant which has an aggregate storage capacity of 100 cubic yards, a weighing unit and a control panel.

The two " Gyramixer " stationary pan mixers incorporated in the batching plant each have an unmixed capacity of 42 cubic feet and a mixed batch output of 28 cubic feet. A further section consists of two conveyors which take the concrete to either shaft and a 2 cubic yard wet receiving hopper to receive the concrete before discharge to the 2 cubic yard roller skips used for transport down the shaft.

Concrete brought down the shaft in 2 cubic yard concrete skips is discharged to a folding chute, from the base of which are led four trunk ranges, thus splitting the concrete equally into four parts. During the placing of the lining provision is made for pipe clamp supports, safety rope support, and also Bunton boxes for cross girders for guide rails.

Twenty shifts are worked each week on this project, the N.C.B. taking over the shafts on Sunday day shift each week for maintenance and testing of equipment. Each shift is of 8 hours duration and consists of : one foreman, one chargehand, one grab driver, two onsetters and eight sinkers. Output from No. 2 shaft during the record-breaking month was some 15,000 tons of rock excavated and 2880 tons of concrete emplaced.

Freezing Procedure

The freezing principle employed when sinking through the water bearing Permian zone at Kellingley consist of maintaining a continuous sheath of frozen strata around the shaft during sinking, by circulating brine through thirty-seven tubed bore-holes extending well into the non-permeable strata to ensure complete sealing of the shaft. For this technique the verticality of the bores is carefully controlled such that they do not intersect the shaft line and in order that each has approximately the same cooling area surrounding each tube. The freezing tubes are lowered as soon as a hole is completed and a small diameter tube is then inserted into the completed column. Connection is then made with the brine mains, the refrigerant flowing down the small bore tube and up through the column to the mains on the

refrigeration plant. The refrigerant is a solution of calcium chloride in water, the freezing point of which is −22 deg. Fah. at a specific gravity of 1·24. At the refrigeration plant, liquid ammonia is evaporated at low pressure in tubular heat exchangers, the latent heat of evaporation being derived from the brine during its passage through the heat exchanger tubes. The ammonia gas is taken from the heat exchangers to high speed compressors delivering to banks of condensers which are cylindrical heat exchangers upon which cooling water is played, resulting in liquefaction of the ammonia before passing out through automatic expansion valves and on to the brine heat exchangers. Each ammonia circuit is independent, the four circuits being used to give the maximum reliability in maintaining brine circulation. Some 1200 lb of ammonia were used in each circuit. The brine circulation was some 70,000 g.p.h., maintained by two pumps, the brine containing some 70 tons of calcium chloride.

The circulation of the brine through the entire system results in long columns of frozen ground being produced round each freezing tube, the diameter of the columns increasing as freezing continues until they merge with one another and an ice wall is formed. Whilst sinking of the shaft is in progress, the refrigeration rate is maintained in excess of the melting rate due to the higher temperature of the surrounding rocks, the ice wall gradually thickening until it extends for some distance beyond the excavation and the unfrozen core has become completely frozen, thus forming one solid cylinder of frozen rock in which the shaft is sunk. When this is achieved, any faulty bore can be isolated from the mains without affecting the progress of the work.

Rotary drilling for the freezing bores began at the end of March, 1958, and was completed in early September, 1958, a total of some 49,450ft being drilled with the boring completed: the refrigeration plant installed, freezing at the site of No. 1 shaft was started on October 27, 1958, the ice wall being closed at the end of February, 1959. Commencing and closing dates for No. 2 shaft were December 15, 1958, and July 9, 1959, respectively, the resulting ice walls formed being some 80ft in diameter.

Sinking in Frozen Ground

The sinking routine in frozen ground was dominated by the necessity of ensuring that the freezing tubes were not damaged by excessive shock waves. Thus in this section, a three-square draw cut, comprising twelve holes, followed by a round of sixty-four holes was adopted and in order to rationalise the drilling as far as possible, the floor of the shaft was divided up into quadrants and the cut, two machinemen being permanently allocated a section. Thus in the cut, the two most experienced drillers were located, each drilling the full depth of 6ft and working on diametrically opposed holes. In the quadrants, the first of the two drillers worked to a depth of 4ft 6in, continuously, the second machineman being permanently engaged in deepening these holes to 6ft. Ice fissures of up to 30ft in depth and 6in wide caused considerable difficulty when drilling throughout the frozen ground. The frictional heat generated by the rotating bit causing a rapid thaw of the ice, which in liquid form was blown up the hole, refreezing in the process. Thus large numbers of holes were rendered useless, by the drill steels becoming completely frozen in their holes. Modification of the drilling machines to allow for high volume blowing of air at the tip, in order to cool the bit and remove from the hole any liquid formed before refreezing took place, met with some success. Integral drill steels with cross bits were used throughout the frozen ground, but did not prove ideal for normal ground. Here integral steels with chisel bits produced far better results.

The amount of explosive to be used in any one round in the frozen area was limited to 150 lb to ensure that excessive shock waves were not set up, which could possibly cause damage to the freezing tubes. The depth of the rounds varied between 6ft and 10ft according to the strata encountered. This limitation of explosives made it necessary to fire twice for each full round of holes bored, the outer or cropper holes being fired separately from the rest of the round. Parallel mains electrical firing was employed.

To reduce charging time to a minimum, the bus-bars were prepared on surface in a priming shed. The bus-bars were laid out in accordance with plans displayed on a wall panel which showed the exact positions for attaching the detonator leads. These leads terminated in " inert " primers which consisted of plaster of paris containing an outer groove for the detonator leads, the detonator being inserted firmly through the centre of the plaster of paris such that it protruded approximately ¼in into the following stick of explosive.

The stage was raised 150ft before firing and the shaft was inspected before it was lowered after firing. With the stage in position, mucking commenced, using four hoppits. Thus, whilst the grab filled a hoppit on the east side of the shaft, the west winding rope dropped an empty hoppit on the west side of the shaft and picked up a full one. When the hoppit on the east side was full the grab swung around and commenced loading on the west side. Loading was always arranged to take place underneath the winding rope carrying the full hoppit to the surface.

The temporary support employed in frozen ground consisted of steel channel rings, suspended on hooks, with dowels inserted in the ground every 5th ring to provide additional security. Behind the steel rings were placed corrugated steel sheets held against the ground by timber poling boards and wedges.

Shaft Lining in Frozen Ground

The sinking and lining routine followed in coal measure strata was to sink 40ft and to line this section immediately. During sinking, the ground was secured by wire mesh and anchor bolts which were placed at a minimum depth of 4ft into the rock. This system could not be worked in the frozen ground due to the presence of the corrugated back sheets which prevented the concrete adhering to the ground. The following procedure was, therefore, adopted :

(1) 40ft of shaft was sunk and back sheets placed only in the top 30ft.

(2) A concrete crib was placed in the bottom 10ft section which was in immediate contact with the ground.

(3) Sufficient waiting time was allowed to elapse before sinking further to allow this crib to gain strength. Only in the first crib, placed in either shaft, was this waiting time required.

(4) A further 40ft of shaft was again sunk, and again only the top 30ft back sheeted.

(5) Another crib was placed in this bottom 10ft.

(6) As soon as this crib was placed, lining of the first 30ft (Item 1) took place.

This procedure was followed throughout the frozen ground, and allowed each crib sufficient time to gain strength to support the 30ft section above it.

The lining was emplaced in 5ft lifts. the shuttering consisting of two 2ft 6in high rings of ¼in steel plate used with releasing segments. In frozen ground, provision was made in every 5ft lift for eight injection pipes, with a further eight being located in the crib ring. The grouting was carried out within ten days of placing any part of the lining, whilst local thawing of the ice was occurring. For each 40ft section, some 20 to 30 tons of cement were injected, using a Boulder grouter.

The grouting was carried out at a maximum pressure of 60 lb per square inch. The mix was prepared on surface and the grout passed down the shaft by a 2in gravity line terminating in a rubber hose connected with the Boulder grouter on the sinking stage.

The majority of lining in the frozen ground was 18in thick, but towards the base of this frozen area, at 460ft, this thickness was increased in steps from 18in to 24in, then to 27in, at which point the frozen ground ended. Below this level the lining thickness was reduced from 27in to 24in, then to 18in and finally to the normal ground lining of 12in.

Concrete Specifications

The specifications required a minimum strength of 4500 lb per square inch at twenty-eight days in frozen ground, the average figures obtained to date being 7000 lb per square inch. In unfrozen ground the specification is for 3000 lb per square inch, the average figure reached here being 6000 lb per square inch at twenty-eight days. During the lining in frozen ground, "Sulfacrete " was employed, Portland cement being used in unfrozen ground. The aggregates were closely checked for organic content, moisture, size, &c., and the aggregate pits were heated with steam pipes to maintain an even temperature and hence control the moisture content. The container on the batching plant was also heated, thus guaranteeing uniformity of mix and moisture content. The mix used in the frozen section was : 0·296 tons cement, 0·429 tons sand, 0·729 tons gravel, 12 gallons water. In the unfrozen ground the mix was : 0·239 tons cement, 0·594 tons sand, 0·880 tons gravel, 18 gallons water.

Hydraulically Operated Cargo Valve

A SIMPLE yet reliable motorised valve for installation in tankers, bulk cargo carriers and passenger ships is being marketed by the Telegraph Construction and Maintenance Company, Ltd. The valve incorporates an hydraulic ram connected to a modified Blakeborough " Flexi-Ring " rising spindle gate valve fitted with a non-threaded spindle in place of a threaded one.

Both the ram, which operates the valve, and the actuator for the valve position indicator are enclosed in an oiltight case, and because the ram is set to close at a pressure of 5500 lb and to open at a thrust of 7000 lb the gate cannot jam in its wedge. The controller can be mounted as required with the valve position indicator adjacent or a console arranged to carry all the switches necessary for operating an entire system by remote control. The power pack consists of an electric motor, a pump, a reservoir and an accumulator if necessary, and the most economical system is one whereby up to three valves can be operated simultaneously. Valve position indication can be achieved by electric or hydraulic means, and the hydraulic actuator is of piston pattern, spring assisted to overcome a head which can be 50ft or more in large tankers.

[Reply Card No. 1135]

LETTERS AND LITERATURE

Letter to the Editor

"JAWERTH" ROPE TRUSSES

SIR,—On returning from holiday, I was very interested to read Mr. Rowbotham's letter in your issue dated July 7 in which he pointed out that he had submitted a design for a 1000ft span hangar in the finals of the R.I.B.A. competition in 1928 using rope trusses. Mr. Rowbotham obviously had a good idea. Perhaps one of the reasons for this present new phase of construction utilising wire ropes lies in the use of a prestressing bed to remove the hysteresis, or variations of cable stretch. The result being that ropes can now be easily made to an accurate length with the same characteristics of a steel rod in that the modulus of elasticity remains constant at the design stress.

The designer of the Mitcham hangar must find some satisfaction in seeing this new form of construction being applied to numerous large buildings on the Continent. Sweden, France and Germany are utilising this form of construction over a wide range of structures. It was interesting to see that at the Soviet Exhibition in London they were showing models of buildings utilising rope trusses for spanning large areas. Doubtlessly this form of construction will spread to this island also and perhaps a hangar having 1000ft span will eventually be built by some enterprising architect or engineer.

With regard to Mr. Rowbotham's remark about the position of the roof coverings for the Le Bourget buildings shown in your edition of June 23, these are temporary buildings and the roof has been suspended for convenience of erection and dismantling. The roof of the Supermarket which is shown under construction in the same article has a roof fixed to the top chords of the truss as befits a permanent building.

K. E. M. WHITE,

Bexleyheath,
Kent.
August 1, 1961.

Book Reviews

Spring Design: A Practical Treatment. By W. R. BERRY, Ph.D., M.I.Mech.E. Emmott and Company, Ltd., 31, King Street West, Manchester, 3. Price 40s.

THE author has had over thirty years' experience in the design of springs and has produced a book which "provides rapid practical methods for designing reasonable springs with the minimum effort from information normally in the possession of the designer." The preface emphasises the importance of line charts (or nomographs) to facilitate the manipulation of formulae and twenty illustrations of such charts are given. The use of nomographs for this purpose is not, of course, a recent design method, as the late J. H. Hyde used the method forty years ago in the design of steel wire measuring springs. (see "Mechanical Testing," Vol. 2 by Batson and Hyde (1922); Chapter X on "Springs"). The book is a treatise on all kinds of springs, many of which are not usually described in text books, and for this reason alone it should find a place on the bookshelf of every spring designer and user.

The excellent work of A. M. Wahl is very fully described and critically examined. The text book formula for stress in an axially loaded helical spring is based on the assumption that the spring functions as a straight bar in torsion. This assumption gives a value of the stress which may be much lower than the actual value. The author states that "Wahl's formula for calculating a correction factor has become the most generally adopted" but he prefers one devised by Bergstrasser which is easier for slide rule work.

There is a well written chapter on "Spring design for fluctuating and cyclic loads and fatigue conditions." It has a brief reference to local increases of stress in engine valve springs due to "surging" but contains no reference to a report by A. Swan and L. G. Savage on "The Surging of Valve Springs." This work was carried out at the Royal Aircraft Establishment for the Springs Research Committee of the D.S.I.R. and published by H.M. Stationery Office as Special Report No. 10 (1928). This Report showed that the increase of stress due to surging could be as much as 40 per cent and that fractures occurred at a point one coil distant from the end, i.e. at the region of the greatest range of stress. The book does not contain any reference to the report of the D.S.I.R. Springs Research Committee published in 1931. This has a Bibliography (Appendix 1) on springs with nearly 100 references, together with abstracts of reports on specific items of research. The author gives particulars, in the text, of sources from which he has derived information, but the value of the book would be enhanced if a separate list of references was included at the end of each chapter.

A special chapter on "Cantilever and Laminated Springs" deals fully with the difficulties in the design of such springs. Page 276 states "it is difficult to believe that anyone could predict the number of times any spring in road use will oscillate." The Report of the Springs Committee, to which reference has already been made, devotes a section on the "Displacement of Vehicle Springs under Road Running Conditions" and D.S.I.R. Special Report No. 8 (H.M. Stationery Office, 1928) contains the results of an investigation by J. H. Hyde. Torsion bars used as springs, which are a special feature on some motor cars, have a chapter devoted to them and their design is fully described. Considerable troubles were encountered during World War I with the failures of springs operating over bad roads and the author states that during World War II "fighting vehicles . . . experienced excessive spring failures during desert warfare." One method of increasing the life of a spring is by shot peening the surface of the metal in order to produce a residual stress in the skin. The final chapter of the book describes briefly the various methods for increasing the life of springs under oscillating stress conditions and then deals fully with the comparatively modern method of shot peening: examples of design are included.

Although some criticism of the book has been given, it does not detract from its value as a practical work of reference but rather indicates points which could receive attention in any subsequent edition.

A Guide to the B.S. Code of Practice for Prestressed Concrete. By F. WALLEY and S. C. C. BATE. Concrete Publications, Ltd., 14, Dartmouth Street, London, S.W.1. Price 12s. 6d.

THE British Standard Code of Practice No. 115 : 1959, like the "First Report on Prestressed Concrete" has not been received by experienced designers as an "unmixed blessing." There are profound difficulties in codifying the comparatively recent technique of prestressed concrete which is still capable of considerable development. Whilst the Code partly recognises this in that it leaves much—perhaps more than other Codes of Practice—to the judgement of the designer, authorities may, nevertheless, often apply the Code indiscriminately to all prestressed construction, thereby limiting the use or development of the medium. This neither is, nor should be, the intention behind the Code. Indeed, there is much data in the Code which is open to considerable difference of opinion and about which the drafting Committee must have found difficulty in reaching unanimity.

The publication of the present Guide to the Code is to be welcomed, not least because of the foregoing. The book reproduces each section of the Code separately and immediately after each section the authors provide the benefit of their experience by detailed explanations, ancillary data, &c. In their comments on parts of the Code on which there is scope for differing views, it is a pity that the authors' treatment is not more critical; but given that their object was to provide an explanatory handbook of the Code as such, they have succeeded admirably.

The authors provide valuable comments on prestressing steel and concrete quality control. Their section on losses of prestress is particularly good, as are their explanations of ultimate load design. In all these cases, much additional and useful data is provided. On the vexed problem of ultimate shear resistance—about which so little rigorous data is available—the authors have done as well as possible. Whilst their treatment is necessarily brief, the important points requiring care are well highlighted.

Some small points of criticism can be made. They are generally matters of omission. The time of transfer in post-tensioned work is not solely a stress criterion. Absolute minimum values are desirable. The friction evaluation should be carried out in the knowledge that sometimes very little friction indeed occurs. There is a case on record of concrete failure during the stressing of a large beam caused by the various losses which had been allowed for (including friction, elastic losses and over-stressing) *not* taking place. In common with most text books, little mention is made of the stress gain in bonded tendons when full load is applied on a beam. Although this is normally small, it is a significant proportion of the losses. On deflections, insufficient emphasis is made in the comparison with reinforced concrete to show that prestressed

concrete construction is usually more flexible in practice.

These are only minor points. The authors have provided an excellent "guide," concisely written, readable and easily assimilated. They include a useful list of bibliographical references. Both the student and the practising engineer will want this book in their library.

Embrittlement by Liquid Metals. By WILLIAM ROSTOKER, JOSEPH M. MCCAUGHEY, and HAROLD MARKUS. Reinhold Publishing Corporation, New York; Chapman and Hall, Ltd., 37, Essex Street, London, W.C.2. Price 64s.

METALS are used by engineers in many different environments, and designers already know that contact of their metals with some aqueous, gaseous, and molten salts in their environment may produce embrittlement, notably where the metal or alloy is stressed either externally or internally and at elevated temperatures. Solid metal components may also be embrittled by contact with liquid metals; during brazing and soldering operations unwelcome cracking of parts or assemblies has been noted and is always to be feared. Steel axle journals in contact with molten metal from overheated bearings, steel springs plated with cadmium and unexpectedly, momentarily overheated have cracked and failed where, but for the contact with molten metal, they would have continued to serve.

The cracking of stressed brass by mercury is nowadays regarded as a metallurgical classic. Perhaps, however, it was the many recent attempts to use the controlled flow of liquid metals as coolants in atomic reactor systems that induced the three joint-authors of this book (Rostoker from the Armour Research Foundation and McCaughey and Markus from Frankford Arsenal) to collect and evaluate the references to embrittlement by liquid metals that have appeared throughout the literature.

The first chapter is a helpfully wide review and twenty or more of the list of sixty-three references are to papers in the *Journal of the Institute of Metals*. References to papers from many German, American and Russian authorities are included. From this it appears that four topics predominate: detection of residual stress in alpha brass, hot dipping processes, welding and other joining processes, and liquid metal coolants for nuclear reactors.

The numerous phenomena, whose observation has thus been reported, seem to indicate that when liquid metal comes into contact with a piece of solid metal there may be: (*a*) no interaction; (*b*) dissolution into the liquid metal; (*c*) solid diffusion of the liquid metal into the solid; (*d*) formation of intermetallic compounds at the liquid-solid interface; (*e*) penetration of the liquid metal between the crystals of the solid, in the absence of stress; (*f*) brittle and premature fracture of the solid metal, when, under external or internal stress, liquid metal penetrates between its crystals.

The other six chapters of this book include a further eighty-four references, most of which relate to aspects of the theory of fracture of metals and the mechanism of liquid metal embrittlement. Some of the illustrations are of unusual interest and beauty; notably those which show the use of radiography in revealing cracks produced in an aluminium alloy by mercury. Others show the crack patterns in an aluminium alloy as a function of the applied stress, and the crack system in an aluminium alloy plate produced by wetting with mercury at an indentation and showing the pattern of residual tensile stresses. One of these illustrations, which pictures the crack pattern in an aluminium alloy plate under biaxial tension when wetted with a mercury amalgam, deserves exhibition as a work of art.

Small as this book is, only 162 pages of 6¼in by 9¼in, it deserves to be provided with a much more complete index than in the present 1½ pages. Having broken new ground in producing this book on what has become a subject of importance to many users of metals, it is to be hoped that the publishers will in due course produce a second edition with a much more adequate index. That will make the book of even more value to the many engineers and metallurgists who will welcome the book because they have specialised interests in preventing, or in some cases deliberately causing, the embrittlement of one solid metal by contact with another liquid metal or alloy.

Hyperstatic Structures. Vol. 2. Worked examples and examples for solution. By J. A. L. MATHESON AND A. J. FRANCIS. Butterworth & Co., (Publishers) Ltd., 4 & 5 Bell Yard, London, W.C.2. Price 60s.

IN this second volume of their work Professors Matheson and Francis round off their study of indeterminate structures. Although it is not absolutely necessary to have the first volume to hand, it is presupposed that the reader has been through it and has access to it. This volume is supplementary to the first in that there is no attempt to duplicate the fundamental nature of that book. It provides a rich assortment of questions largely taken from university papers and at the beginning of each section works out one or more examples thoroughly and in detail, using the different methods which are generally available. Thus it considers energy methods, minimum potential energy, virtual work in one chapter; in another deflections, introducing all the methods normally used to calculate them; and so on, dealing with linear elastic structures, rigid jointed frames and arches. Finally it ends with two contributed chapters, one on stability of struts and frameworks by Dr. Murray and one on matrix methods by Dr. Livesly.

In their introduction the authors defend themselves against a supposed attack on the usefulness or otherwise of providing a textbook of examples. They need have no fear. With the emphasis today on rigorous solutions solved using digital computers it is imperative that the engineer of tomorrow should be able to set down the fundamental equations of the structure and to see the fundamental relationship of one method of solution with another. In previous years it was more useful to know what assumptions to make to get a solution in reasonable time. One, however, gets a little shock from time to time in looking through the examples to see a problem solved exactly—a problem which in the design office would be reduced to a very simple structure by making certain assumptions in the calculations (but not necessarily in the detailing !).

An engineer would like to feel that all his design staff were familiar with all the methods used in this book. A thorough knowledge of them is indeed fundamental to the practising engineer, for when he then uses short cuts, he is at least aware of what he is doing. This book can be thoroughly recommended to the advanced student who, if he can master the methods, will be a very useful member of the engineering profession.

American Building Art: The Twentieth Century. By CARL W. CONDIT. Oxford University Press, 417, Fifth Avenue, New York, N.Y. Price 15.00 dollars.

IN this second volume Professor Condit continues into the twentieth century his history of structural form. In one sense it is an anti-climax in that it describes an engineering world in which the majority of engineering discoveries relating to structural form had already been made and where the spirit of daring had been replaced by mere grandiosity. Even the author is aware of this, yet he truthfully and doggedly pursues his historical study even when the ground is stony. There are, of course, bright spots—the long-span suspension bridges and the large dams—but generally one has the impression that great things can be accomplished by the power of money rather than by skill and ingenuity. In this book he uses the same system as before, tracing the structural form as developed in different kinds of buildings, bridges, dams and expressways. What he has to tell us is instructive and readable, but, as he says, "The social character of the United States still tends to be unconducive to original speculation and development," so that the subject matter is not exciting. Maybe he does not do justice to some of the smaller concrete structures in the States, but perhaps he does not recognise Candela's offspring as truly American building art. In this he is being strictly accurate.

On the subject of dams one could question his claim that the United States has maintained undisputed pre-eminence in this field, but that is not to scorn the many excellent structures they have built. The chapters, however, which the reader may find especially rewarding are his last two—The Metropolitan Parkway and An Architectural Appraisal. The first of these should be read by those planning our roads (and the "rail-road" correspondents in this journal). One phrase may be quoted: "The simple truth is, however, that the programme (building expressways) will only prove to be a somewhat slower way to exterminate cities than the release of nuclear weapons over them." The second is useful reading for all architects and engineers; here he argues that the shallow and lifeless architecture of our time is but a reflection of the life mankind leads in the twentieth century.

To sum up, this book is not so interesting as his previous volume; no doubt because what he now describes is nearer in time. But his reflections on the reasons for various forms are well worth reading and indeed give much food for thought.

Fast Reactors. By R. G. PALMER, B.Sc., and A. PLATT, B.Eng., Ph.D. Temple Press, Ltd., Bowling Green Lane, London, E.C.1. Price 12s. 6d.

THIS book, one of the Temple Press "Nuclear Engineering Monographs" series, is written as an introduction to the subject of fast reactors. It covers the main physics, engineering and metallurgical aspects of fast reactors and indicates the problems that must be solved before it will be possible to proceed to the design of an economic and safe power plant based on such reactors. These problems, complex and difficult as they are, have become less urgent in the present context: first, because of the slowdown of the nuclear power plant programme in Great Britain, and secondly because the reserves of suitable uranium ores are larger and more widespread than they were estimated to be a few years ago. Nevertheless fast reactors have now been developed to the stage where their proponents (presumably

LETTERS AND LITERATURE (Continued)

including the authors, both from Dounreay) "are sure that they can be made economically competitive with any other power plant, fissile or fossil fuelled." Be that as it may the authors have produced an excellent introduction to the subject. Like the other monographs in this series it is, of necessity, concise and it is so much the better because of that. In six chapters it covers the choice of materials, including liquid metal coolants and their heat transfer properties, and the steady state and transient characteristics of fast reactors. A brief but useful bibliography is included.

Nuclear Engineering. By GILBERT CAHEN and PIERRE TREILLE. Translated by Gilbert M. Melese. Prentice-Hall International Inc., 28, Welbeck Street, London, W.1. Price 45s.

THE expectation of cheap nuclear power has not materialised. The initial fundamental work generated an optimism which has not been translated into insurable hardware and viable economics. This dichotomy between a sound foundation and an uncertain application is reflected in the recent bibliography, and this book falls into the same pattern.

First published in 1958 under the title of *Précis d'Energie Nucléaire*, the book is intended to be complete, up-to-date and "suitable for an introductory or survey course in nuclear engineering." The principles of nuclear reactions are presented with a refreshing amount of useful numerical work, the examples are imaginative, and there is a particularly cogent account of particle accelerators. The engineering problems of nuclear power generation are, however, very briefly glossed over. Little attention is turned to problems outside the reactor core, while on core problems there is much that is incomplete and in parts misleading. This is particularly true of a very brief section on heat removal, and the account of the reactivity variation with burn-up for natural uranium fuel. A solid engineering approach is, however, too much to expect and the intelligently presented reactor descriptions are, though incomplete and not wholly up to date, useful; the book is a welcome addition to the libraries of the multiplying nuclear engineering courses.

Field Measurement of Sound Insulation Between Dwellings. National Building Studies Research Paper No. 33. By P. H. PARKIN, H. J. PURKISS, and W. E. SCHOLES. H.M. Stationery Office. Price 35s.

THIS treatise of about 600 pages gives the results of airborne and impact sound insulation measurements made by the Building Research Station between 1945 and 1956.

An earlier publication of the Building Research Station (research paper No. 27) described investigations in which a method of classifying sound insulation in houses and flats was proposed. In applying this method, the designer needs to know the probable performance (as a sound insulator) of the various systems of construction which he is considering. It is not possible to use any simple classification of methods of construction, and the only adequate guidance is given by actual measurements made in buildings, related to a detailed knowledge of the particular type of construction concerned. Such measurements have been made systematically at the Building Research Station and here we have the bulk of the results, most of which have not been previously published, even though they relate to work done five or more years ago.

The basic information is given in 464 data sheets, each containing the results of one or more measurements of a specified construction. Airborne and impact insulation figures are given at each of the frequencies of measurement, together with a detail of the partition measured and a plan showing the immediate supporting structure. All results relate to houses or flats, and they have been corrected so that they are comparable. Data for similar partitions are grouped together, and some analysis has been made of the similarities and differences within and between groups.

Apart from this extensive presentation of results, a brief account is given of present theory on sound transmission through structures. The British Standard method of measuring insulation and the accuracy of the measuring techniques are also discussed.

Modern Dielectric Materials. Edited by J. B. BIRKS, B.A., Ph.D., D.Sc., F.Inst.P., A.M.I.E.E. Heywood and Co., Ltd., Carlton House, Great Queen Street, London, W.C.2. Price 42s.

THE scale on which new dielectric and insulating materials have been introduced, and older ones improved, in the past few decades, makes this survey of the present position particularly opportune. The materials dealt with by specialist authors are paper, hydrocarbon insulating oils, chlorinated hydrocarbons, natural and synthetic rubbers, synthetic high polymers, silicones, ceramics, glass, mica and micanite, and fibres and textiles. In each case an account is given of general characteristics and production of the material before considering its behaviour as a dielectric. The book provides much useful background information for users of these materials in the electrical industry, as well as for physicists and chemists chiefly concerned with their production.

The Elementary Principles of Reinforced Concrete Design. By W. H. ELGAR, M.A., M.Eng. The Architectural Press, 9-13, Queen Anne's Gate, London, S.W.1. Price 18s. 6d.

AN introduction to the subject for students of architecture and building surveying is aimed at, so the subject matter relates to buildings, and to relevant Codes of Practice. However, load factor design and prestressing are explained in principle. It is considered beyond the scope of the book to give fully worked examples of structural design, those calculations included in the text being illustrative of the principles of design which the book explains.

Books of Reference

Year Book of Heating and Ventilating Industry, 1960–61. Technitrade Journals, Ltd., 11–13, Southampton Row, London, W.C.1. Price 15s.—This book makes available up-to-date information on the Heating and Ventilation Industry and includes authoritative articles on "Design Problems of Radiant Heating," "The Thermal Behaviour of a Building" and "Boiler Water Treatment." There is a contractor's review of the year followed by an extensive index of heating and ventilating literature, and a selected list of British Standards. Model Byelaws: Series XXI, The Prevention of Waste, Undue Consumption, Misuse or Contamination of Water is reproduced. Sections of the book relate to labour agreements, wage rates, working conditions, standard conditions of trading, &c., and trade information for those concerned with heating and ventilating contractors. The volume is issued in collaboration with the Association of Heating, Ventilating and Domestic Engineering Employers.

Packaging Directory, 1961. The Tudor Press, Ltd., 75, Carter Lane, London, E.C.4. Price 21s.—This is a comprehensive guide to all aspects of packaging, and the contents are divided into seven main divisions, beginning with the index which lists eighty-eight principal items. This is followed by the buyers' guide which occupies 192 pages, and is subdivided into five parts entitled: containers and closures, materials, packaging machinery and equipment, mechanical handling, and services. Under the general title "Organisations, Associations and Consultants" are four groups, namely: official organisations, design organisations and associations, packaging consultants, and European Packaging Federation members. Foreign firms, their products and agents are listed, and there are a directory of trade names and an alphabetical list of names and addresses of manufacturers and suppliers.

Books on the Chemical and Allied Industries. Compiled by L. R. Day, M.Sc. H.M. Stationery Office, London. Price 12s. 6d.—This volume has been compiled from a subject catalogue in the Science Library to enable users to take advantage of the books available in the library. The books listed in the catalogue are arranged in broad subject groups selected from the Universal Decimal Classification, and a list of these groups with their associated classification numbers appears at the beginning of the book. There are also indices relating to subjects and authors. Copies can be obtained from the Science Museum, London, S.W.7 or from H.M. Stationery Offices.

Heat Bibliography, 1959. National Engineering Laboratory, H.M. Stationery Office, Edinburgh. Price 20s.—This bibliography, which contains over 400 pages, is the sixth of a series prepared by the Heat Division, National Engineering Laboratory. Material noted during 1959 is listed, and the source stated. Many references are classified by subject and the whole set out in alphabetical order, ranging from Analogues and Atomic Energy, Chemicals, Radiation to Thermodynamics.

Books Received

Automatic Control and Computer Engineering. Edited by V. V. Solodovnikov. Translated by J. Yeoman. Pergamon Press, Headington Hill Hall, Oxford. Price 100s.

Plastic and Elastic Design of Slabs and Plates with Particular Reference to Reinforced Concrete Floor Slabs. By R. H. Wood. Thames and Hudson, Ltd., 30, Bloomsbury Street, London, W.C.1. Price 63s.

Handbook of Thermophysical Properties of Solid Materials. Vol. 1: *Elements (Melting Temperature above 1000 deg. Fah.).* Revised Edition, 1961. Compiled by Armour Research Foundation. Pergamon Press, Headington Hill Hall, Oxford. Price £33 per set of five volumes.

Lehrbriefe Für Kältechnik. Nos. 21-25. Editor-in-chief: Professor Helmut Weimar. Published by the Technical Committees of Refrigeration Industry Working Group and the Main Section "Refrigeration" of the Land Guilds' Association (Bavarian Mechanics). Karlsruhe: Verlag C. F. Müller. Price (with binder) DM.7.70.

Combustion and Propulsion. Fourth Agard Colloquim, April 4-8, 1961, High Mach Number Air-breathing Engines. Edited by A. L. Jaumotte, A. H. Lefebvre and A. M. Rothrock. Published for the Advisory Group for Aeronautical Research and Development, North Atlantic Treaty Organisation, by Pergamon Press, Headington Hill Hall, Oxford. Price 105s.

Electrical Research Laboratory, Rugby

A new research laboratory to serve the interests of A.E.I., Rugby, Ltd., has been built on a seven-acre site at Mill Road, adjoining the company's Rugby works. The laboratory, which is closely linked with other branches of the A.E.I. research organisation, is concerned with research and development aimed at the introduction of new devices and the improvement of the company's existing products and processes. A short description of the laboratory and some of its activities is given here.

THE research laboratory established in a 1924 by The British Thomson-Houston Company, Ltd., has recently been rehoused in a new building as the first part of a research centre which will serve the manufacturing divisions of A.E.I. (Rugby), Ltd. It will be closely linked with the corresponding laboratories of the associated companies to form part of the research organisation of Associated Electrical Industries, Ltd.

The new laboratory (illustrated above) is built on a seven-acre site at Mill Road, on the boundaries of the area occupied by the company's Rugby works. It consists of a three-storey building about 370ft long with a floor area of 45,000 square feet, containing various laboratories, a reception area, library, lecture theatre, conference rooms and offices. The basic requirement was flexibility, to allow for growth and rearrangement in accordance with changes in emphasis on particular items of research, but it was felt that the working environment should not give the sense of impermanence that is usually associated with "temporary" buildings. Mullions at 4ft spacings allow internal partitions to be erected at any 4ft interval along the length of the building. The main corridors, 8ft wide, are offset from the axis to give rooms 24ft wide on the south side of the building and 9ft on the north ; the latter are mainly suitable for offices and the former for laboratories. A laboratory with direct access to the corridor can, therefore, have a width of 24ft and a length of any multiple of 4ft. To allow for the weight of research apparatus the upper floors are designed to carry a load of 250 lb per square foot.

Ventilation is by a "Plenum" system designed for six changes of air in the south facing rooms and four changes per hour for those facing north. The incoming air is drawn through coarse and fine filters to remove particles down to sub-micron size, and is heated and discharged into the rooms through diffusers fitted at 4ft intervals. These diffusers are adjustable to project the air along the ceilings in the winter or downwards in the summer. Pipes for supplementary heating are installed in the ceiling. The double glazed windows are normally closed but can be opened if required. Artificial lighting is provided by 125W, 8ft fluorescent lamps in recessed ceiling fittings with egg-crate louvres. In the corridors the fittings are similar but they are arranged in tandem to give the effect of a continuous line of light.

The partitions, on a standard 4ft module, are sheet metal faced with enamel finish and a filling of thermal and acoustic insulation. A central service duct mounted just above bench level gives ready access to mains supplies at various voltages.

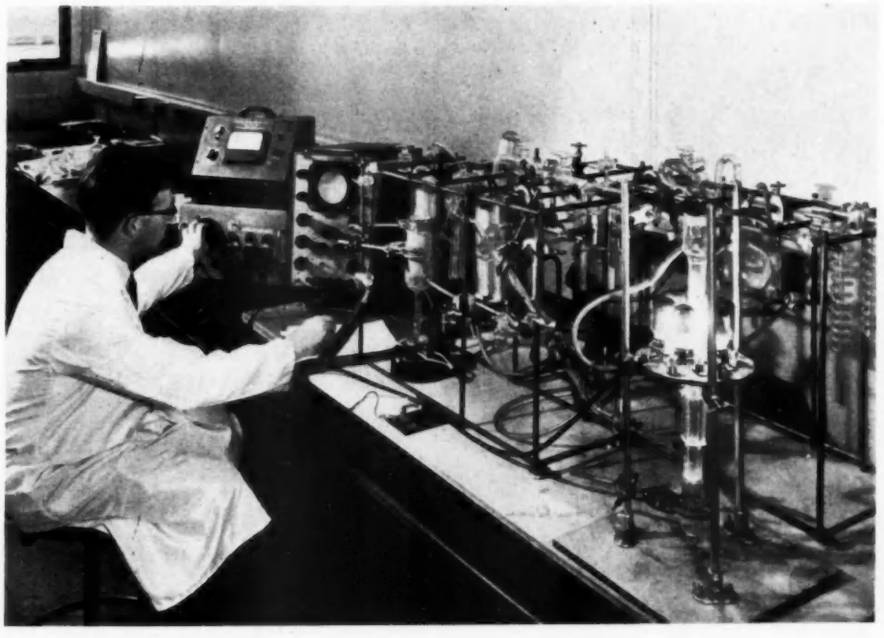
Typical Research Activities

The work done in the laboratory covers a wide scope, impinging on all the manufacturing interests of the company and ranging from fundamental research to appraisal pre-production as an aid to the rapid application of research results to production methods.

Semiconductors.—A good example of intensive work devoted to the translation of a completely new device from the research laboratory to full-scale production is seen in semiconductors such as germanium and silicon and some of their derivatives.

Silicon, for example, is the starting material for many of the semiconductor materials now being studied in these laboratories (as illustrated here). Transistors rated at 5A and silicon-controlled rectifiers rated at 150A and up to 400V are undergoing appraisal before production to establish the feasibility of large scale manufacture and to design devices for advanced circuit work. Preliminary research work is in hand on even larger devices.

In the quest for rectifiers capable of operating at higher temperatures than silicon, other materials are being investigated. They



Apparatus used for studying the surface properties of silicon semiconductor devices

include aluminium antimonide, which can be prepared in the form of single crystals by the usual "pulling" method or by zone refining. Silicon carbide also offers promise as the basis of semiconductor devices at high temperatures. There are major difficulties in growing crystals of silicon carbide—a compound which does not melt but decomposes directly into vapour at temperatures above 2000 deg. Cent. Nevertheless this work has reached a point which made it possible for a rectifier operating in a furnace at more than 400 deg. Cent. to be exhibited on the A.E.I. research stand at the recent British Trade Fair in Moscow.

Direct Conversion of Heat to Electricity.—Two unorthodox methods of converting heat directly into electricity which may be of increasing practical importance are being studied. One makes use of the thermionic effect whereby electrons are emitted from a heated cathode and are attracted to the nearby anode causing current to flow in an external circuit. The current is small unless positive ions can be introduced into the space between the cathode and the collector plate. At present the laboratory is concentrating attention on a study of materials that might be suitable for the cathode and anode and on practical means of introducing caesium ions into the intervening space. The second method, based on the thermoelectric effect, involves the development of two suitable semiconductor materials which can be joined together to form a thermocouple to generate electricity by heating one junction and cooling the other. During our tour of the laboratory we saw a demonstration of a small electric motor driven by an experimental 10W thermoelectric generator consisting of six semiconductor thermocouple elements connected in series, the source of energy being the heat from a propane gas burner.

D.C. Motor with Semiconductor Commutator.—One of the possible applications of semiconductors to rotating machines that the laboratory has been studying is that of replacing the conventional carbon brush and copper segment motor by a static array of semiconductor switches, which must be operated in sequence and in step with the rotor. The model demonstrated during our visit is an experimental 24V d.c. motor, rated at about $\frac{1}{4}$ h.p.; it incorporates six 5A silicon controlled rectifiers which are triggered in pairs through a special form of rotating transformer (called a "magnetic distributor" by analogy with the ignition distributor of an engine) which consists of a transformer having a single primary winding excited by a free-running oscillator and a series of secondary coils connected to the semiconductor-controlled rectifiers. As the rotor revolves, the magnetic circuit is coupled to each successive pair of secondary coils by a rotating yoke.

Two other exhibits illustrated possible uses of silicon controlled rectifiers. One showed a reversing motor drive in which the rectifiers are phase-controlled by transistor firing circuits to give a variable full-wave rectified supply to a d.c. motor in which tachometer feedback is used to produce a speed regulated system. The second showed controlled rectifiers being operated back-to-back in a series-parallel circuit to supply a 250V 3kW lamp with phase control to give a variable light output.

Gas Discharge Physics.—A typical example of fundamental work with a utilitarian object is the detailed investigation, both experimental and theoretical, to establish a fund of knowledge and data on gas discharge physics which will enable the laboratory to design discharge lamps with certain desired characteristics, without expending unnecessary effort on a programme of measurements covering all possible combinations of variables. A detailed theory of the discharge has been developed. It is of interest intrinsically and also as a guide to subsequent experimental work and its interpretation. It involves a knowledge of the behaviour on an atomic scale of the filling gases and of the collisions and interactions causing the emission of the ultra-violet radiation which is finally converted by the phosphor coating on the tube wall into visible light output. The detailed treatment leads to complicated mathematical equations, and it is only the availability of large-scale digital computers which has made the problems soluble. New techniques utilising a computer have been developed and highly successful results obtained.

Nuclear Reactor Alloys.—In recent years the need has arisen for new alloys in the highly exacting environment of nuclear reactors. These alloys must combine high strength and creep resistance at elevated temperatures with a minimum absorption cross-section for neutrons. In the laboratory a very interesting series of alloys has been developed, based on magnesium, which have the required properties for use at temperatures as high as 500 deg. Cent. as structural components in fuel elements for reactors. These alloys are now being appraised by the U.K. Atomic Energy Authority and the engineering consortia.

An Electrostatic Flue-Dust Monitor.—This instrument has been developed for measuring and recording the concentration of fly ash in the flue gas from generating station chimneys. A prototype has been in continuous operation at Hams Hall power station for twenty months. This equipment measures the total surface area of all dust particles passing through it. The dust particles, which may have diameters as small as 0·1 microns, are charged in proportion to their surface area in the corona discharge surrounding a high-voltage needle. The charged particles then pass into an annular electrostatic precipitator where their charges are collected and constitute a small direct current. This current is amplified to indicate on a meter or recorder, and to operate an alarm.

The monitor is designed to operate at generating stations, where it is normally mounted in the flue ducting leading from the electrostatic precipitator to the chimney. The sampling orifice is placed in a position of average velocity conditions, and the outlet diffuser is designed to assist the gas flow through the monitor so that sampling is made isokinetically, that is without change in the flow velocity.

Tests made so far suggest that this system of monitoring should find a useful application in flue-dust control in fuel burning power stations*. By suitable choice of materials and by air purging it should be possible to avoid corrosion and fouling of the sampling tubes and electrodes. In addition adequate heating and lagging of the equipment prevents condensation and thus reduces corrosion, besides avoiding the generation of spurious e.m.f.'s by electrolytic action.

Electric Steel Melting Load.—Electric arc furnaces used in the manufacture of steel impose a very heavy electrical load, which varies at low frequency in a random manner. This behaviour causes a corresponding fluctuation in the mains supply voltage and leads to objectionable flicker of domestic lamps and television screens.

Whenever similar furnaces are operating together on the same supply the amplitude of flicker is multiplied and statistical theory predicts a multiplying factor equal to the square root of the number of the furnaces. The laboratory has now confirmed this prediction for furnaces (up to six) with the model shown during our visit. In this model each furnace is simulated by a mercury arc tube, providing a random contact. The fluctuating voltages across the tubes are added, and are displayed on a cathode-ray oscilloscope. At the same time, the counter is operated whenever the voltage exceeds a preset level and this information is collected for statistical analysis.

Metal Cutting.—From its early days the former B.T.H. Company has been actively interested in improved methods of machining metals and on the development of new materials for cutting tools. This tradition is being maintained in the new laboratories with the same general objective—that of improving productivity and lowering the cost of metal removal, by carrying out fundamental investigations into various aspects of machining operations. Developments such as the introduction of sintered carbide materials (e.g. "Ardoloy AK") for cutting tools involve close co-operation between the laboratory group that develops these materials, the group that evaluates them by extensive tests, the factory that produces the materials and, finally, the works departments in which the tools are used. Special methods have been devised for the evaluation of tool wear by measurements of the scars and craters produced on the tool tips, the results being processed by statistical methods.

Some aspects of this work have been described elsewhere†. For example the influence of profile geometry on tool wear and cutting time has been confirmed by tests on two 4in diameter face milling cutters *A* and *B* ground to the following approach angles: *A*, 45 deg. and *B*, 60 deg., the clearance angle being $8\frac{1}{2}$ deg. in both cases. In tests on 40-ton carbon steel cutter *B*, working at a feed of 16in per minute, removed 50 per cent more metal than cutter *A* working with a feed of 10in per minute (the other conditions being the same for both tools) for a land wear on the clearance face 0·02in wide. This improvement was attributed to the chip thinning effect caused by the greater approach angle of cutter *B*. Further tests showed that when the clearance angle of cutter *B* was altered to $11\frac{1}{2}$ deg. and that of cutter *A* to $9\frac{1}{2}$ deg. the output of *B* was twice that of *A* while the rates of cutting remained in the ratio of 1·6 to 1.

Other Activities.—The Rugby laboratory has developed a 10kW electron beam furnace, for the Culcheth laboratories of the United Kingdom Atomic Energy Authority, for purifying certain refractory metals. A point of special interest about this furnace is that, to prevent contamination of the cathode during melting, the equipment has separately evacuated compartments for the electron gun and for the melt

Another product recently developed at Rugby is a high-efficiency c.w. power source to provide a continuous output of 20kW at 915 Mc/s for dielectric heating.

The laboratory is developing a very elegant method of coating electrical windings with insulation, using a fluidised bed of the insulation in powder form. Briefly, the method is to heat the part to be coated (a wound stator for example) to a temperature just above the melting point of the insulating powder and then immerse the part for a few moments in a fluidised bed of this powder. The part is

* "An Electrostatic Dust Monitor," by D. H. Grindell, *Proc. I.E.E.*, Vol. 107, Part A, No. 34, August, 1960.

† "The Wear and Evaluation of Metal Cutting Tools," by J. Taylor, *Machinery*, October 12 and November 2, 1960.

thus encapsulated in the insulant. Masking can be used before dipping, to shield any parts that are not required to be coated.

Work is being done on the development of an overload relay having a response time that varies inversely as the magnitude of fault current; and a relay system for the protection of power networks, which operates by monitoring the impedance of the line.

Finally some examples of the more fundamental research work may be mentioned. Methods involving radioactive tracers are being used to follow the distribution and diffusion of impurities in crystals of semiconductors and for activation analysis to determine trace impurities. Vacuum fusion gas analysis is being used to determine the oxygen content of metals such as beryllium and in vacuum extraction to determine the hydrogen in metals. Electron microscopy and electron diffraction are being applied to the study of reactor materials and, in particular, to observations on precipitation in magnesium alloys.

"Dragon" High-Temperature Reactor Project

Last week the O.E.E.C. European Nuclear Agency published its second annual report (covering the year ended March 31, 1961) on the "Dragon" High-Temperature Reactor Project which is being built in the United Kingdom at Winfrith, Dorset. The report is in three parts. The first two describe in some detail the progress of the work under two headings: research and development; and reactor design and construction. The third part deals with administration including staffing matters, finance and the placing of contracts. These three parts of the report are summarised below.

THE main aims of the "Dragon" project, which was set up under a five-year twelve-nation* Agreement signed in Paris on March 23, 1959, are to design, build and operate a 20MW (thermal) high-temperature gas-cooled reactor experiment, and to carry out a programme of research and development to explore the practical possibilities of this reactor type, and the technical problems (particularly in connection with core construction and fuel) resulting from operation with temperatures in the neighbourhood of 1500 deg. Cent. in the core.

The first annual report, published in August, 1960,† included details of the history and structure of the Project together with a broad survey of its technical objectives, as well as an account of the first year's work. The second report (summarised below) is confined to a record of progress during the year under review.

Some of the highlights noted in the report are the rapid progress of construction work on the reactor experiment (illustrated); the finalising of a great deal of the detailed technical design; the large numbers of research and development problems being studied; and an agreement in principle that the enriched uranium for the "Dragon's" first fuel charge will be supplied by the U.K.A.E.A.

Over 400 contracts, with a total value of £4,288,363, had been placed by the end of March, 1961. Of these 244 (total value £1,882,996) were for research and development work and equipment, and 164 (value £2,405,367) were for the reactor experiment itself. An international system of tendering has ensured that manufacturing organisations in all countries participating in the projects have been able to submit tenders. Some of the contracts awarded are listed at the end of this article.

The report estimates total expenditure for the year 1960–61 as £2,379,000 (compared with £710,000 in 1959–60), and predicts a budget of £4,703,000 for 1961–62. No change is foreseen in the total estimated expenditure of £13,680,000 during the five-year life of the project.

The project staff now numbers 244, or very nearly full planned strength. In addition a number of engineers and draughtsmen have been engaged on short term contracts.

Annexed to the report are charts showing the composition of the staff by country and by grade; the senior staff structure; the members of the Board of Management and the General Purposes Committee (the two international committees responsible for the direction of the project); a list of all major contracts placed in 1960–61; and tables giving estimates of expenditure and commitments throughout the life of the project. There is also an appendix describing the fission product and helium purification plant which will be used to keep down the level of activity in the primary (helium gas) cooling circuit of the reactor.

Research and Development

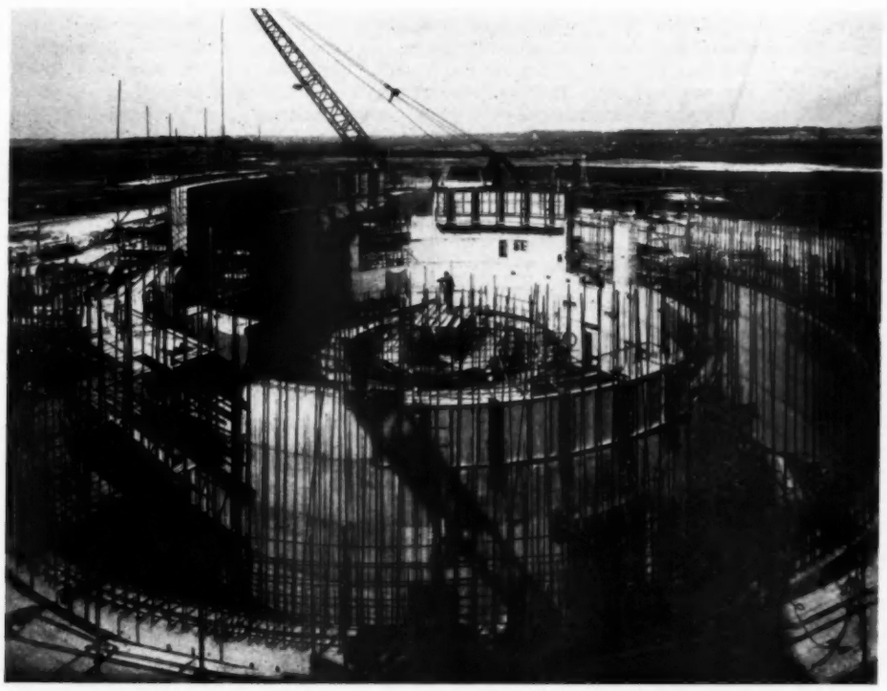
Calculations for the "Dragon" reactor experiment have been continued using more refined methods and new data available from the "Zenith" experiments at Winfrith. These experiments have included fine structure flux measurements, control rod calibrations, flux and spectrum measurements, determinations of conversion ratios and temperature coefficients of reactivity.

Reactor kinetics and safety studies have been carried on throughout the year, covering such things as loading procedures, behaviour at reduced coolant flow, the approach to full power, deposition of activity in the circuit and evaluation of leakage of fission products from the fuel boxes.

Heat transfer studies have continued on the three rigs at Winfrith, and a contract has been placed for construction and operation of a single reactor channel high-temperature heat transfer rig. Construction of the seven fuel element experiment rig (described below) has been completed and the rig is now being commissioned. It has been decided not to proceed with renting the mass transfer rig being built by the United Kingdom Atomic Energy Authority which was mentioned in the first annual report. Instead smaller rigs are being used or are under construction. The rate of carbon deposition under different circumstances is being investigated.

Further results from low-temperature absorption measurements and theoretical interpretations of these results have led to changes being made in the design of the helium processing plant. The pilot plant, shortly to be commissioned at Winfrith, should give valuable information on the performance of the low-temperature adsorption unit, oxidiser unit and freezer unit.

Graphite.—Work on the impregnation of graphite has continued, and further work has been initiated to try and produce better graphites. By the end of 1960 most of the



"Dragon" high-temperature gas-cooled reactor, an O.E.E.C. project under construction at the U.K. Atomic Energy Establishment, Winfrith

* The United Kingdom, the six Euratom countries (Belgium, France, Germany, Italy, Luxembourg, and the Netherlands) represented by the Euratom Commission, Austria, Denmark, Norway, Sweden, and Switzerland.

† Summarised in THE ENGINEER, pages 302–306 and 338–341, August, 1960.

graphite requirements had been finalised with the exception of the material for the core itself. It has been decided that the "Dragon" project should try to develop its own low-permeability, fine-grain graphite, while parallel work is encouraged with the aim of improving the quality of the CY119 grade material to meet the specifications of the project. Work on graphite impregnation has been concentrated on developing the production process. Good experience has been gained on the treatment of fuel element components for the seven-element experiment described below; as a result no major problems are anticipated in meeting the design requirements of the reactor experiment, provided that a satisfactory base stock material becomes available.

Dimensional changes that occur during impregnation are a major problem, and it may be necessary to modify the original dimensions in the light of experience. Depending on inhomogeneity of the stock there is some lack of uniformity in the dimensional changes (contractions). Therefore where close tolerances are essential (such as the mating faces of joints) a final machining operation may be necessary.

Fuel Elements.—Studies have also continued on the migration of fission products inside the fuel compacts and through the graphite walls of the fuel boxes. The work on fuel elements has been concentrated on building up the necessary facilities to provide information for specifying fuel for the reactor experiment and for producing fuel inserts for irradiation experiments.

With regard to the fuel boxes, studies of the reaction of zirconium with graphite and the properties of the resulting zirconium carbide suggested that the zirconium braze might fail in continued service at high temperature. Test results supported this forecast and alternative methods of sealing are being sought. Present indications are that molybdenum disilicide is better than zirconium but there is not enough evidence to justify confidence in those brazes for service at temperatures up to 1750 deg. Cent.

Developing and Testing of Components.—Component development and testing has increased during the year and tests not originally envisaged have had to be carried out. The project has continued to study problems arising with bearings in pure helium, with gas bearings, with leak tightness, with control rod mechanisms and with loading of the fuel elements. Considerable effort has also been spent in trying to develop a high temperature metal-sheathed thermocouple for use in contact with graphite.

In-Pile Irradiation Experiments.—During the year contracts have been placed for the construction of irradiation rigs and for the rental of space in several reactors in Europe. Capsule irradiations are to take place in the Danish DR-3 reactor at Risø, in the Swiss reactor at Würenlingen and in the Dutch reactor at Petten. A loop will be put in the Swedish R-2 reactor in Studsvik for studying fission product release. Arrangements have been made for post-irradiation examination of the capsules at Studsvik. Design work has been completed and construction started of the in-pile mass transfer loop to be put in the Belgian BR-2 reactor at Mol. The British "Pluto" Loop-A has reached the final stages of commissioning and will be rented by the project during the coming year.

The capsule to be irradiated in the DR-3 reactor contains a representation of the fuel rod tube housing three full-scale fuel boxes and is an advanced version of that designed for the original "Pluto" programme (now replaced by the DR-3 programme). The specimen will work in the reactor at about 70W per cubic centimetre with a temperature of 1400 deg. Cent., the power rating being slightly lower than the average value for "Dragon," which is about 85W per cubic centimetre. Essentially the experiment is designed to study burn-up and the capsule fuel content is lower than in "Dragon" because the flux in DR-3 (9×10^{13}n per square centimetre) is considerably higher than is envisaged for "Dragon."

Capsule irradiations in "Dido" (A.E.R.E., Harwell), and post-irradiation examination have been completed. This work has given useful information for fuel element development, extending confidence in this type of fuel at temperatures up to 1000 deg. Cent., and has shown that no major unsuspected problems are likely with the proposed fuel element system for "Dragon."

Seven-Fuel-Element Experiment.—This experiment will enable the operational performance—heat transfer, mass transfer and mechanical stability—to be studied in a "core" consisting of a set of seven fuel elements. The elements are electrically heated in helium at the reactor design conditions of temperature, pressure and mass flow, and the rig is instrumented to measure strain, vibration, element surface and bulk gas temperatures.

The experimental plant is being made by C. A. Parsons and Co., Ltd. The main circuit consists of a pressure vessel, connected by coaxial pipes to a single pass heat exchanger and a gas-bearing helium circulator. The seven elements are surrounded by a graphite reflector, and mounted on a grid structure supported by a cylindrical steel cradle. The cradle is suspended by a top flange resting on brackets fixed to the pressure vessel wall. Cool gas from the circulator enters the vessel through the outer co-axial pipe, flows down the space between cradle and reflector, and passes through holes in the grid to enter the core channels. After passage through the core, the gas enters a top plenum chamber of stainless steel and leaves the pressure vessel through the inner pipe connected between this chamber and the heat exchanger. The gas is cooled and flows to the input of the circulator, the output of which returns to the pressure vessel feed pipe. By-pass valves across the heat exchanger and circulator control the gas inlet temperature and mass flow.

The fuel elements are compacted by the pressure drop across the core, and the inlet and outlet gas flows are separated at the top of the core by graphite seal segments as in the "Dragon" design.

Installed in each fuel tube is a graphite heater rod. Three zones, the centre rod, the remaining six rods of the centre element, and the outer six elements (forty-two rods) can be controlled independently.

The heater rods were developed to dissipate 77kW each. Further developments comprised co-axial conductors for 3000A per phase, measuring equipment such as strain and capacitor gauges for installation on the rod surfaces, and a test rig for service testing the heaters and gauges. Degassing problems of the graphite entailed the construction of a furnace for heat treating the graphite before assembly of the core.

The seven-element experiment reached its commissioning stage in April, 1961. The experiments will be carried out with nitrogen as a heat carrier until a gas-bearing blower is available for helium operation.

Reactor Design and Construction

The design of the reactor has been reconsidered and the detailed requirements of specific items assessed. It has not been necessary to make any fundamental change to the design of the reactor as a whole but improvements have been made to particular items. The requirements of almost all the plant have been defined and in most cases the broad design features have been decided upon.

The manufacture of the pressure vessel has proceeded satisfactorily and experimental results indicate that a high standard of leak tightness will be obtained. The main shield plug has been reconsidered and a more effective design produced.

Considerable progress has been made in finalising the design of the core. The strength and cooling of the fuel boxes has been improved and the introduction of a shortened fuel element spike has allowed for fission product traps to be incorporated in the lower ends of the fuel rods. This change has also led to an improved bottom reflector. The cooling of the "static" reflector has been revised and the design of the "live" reflector is now being reviewed. Various designs of the core seal and unclamp mechanism have been considered and a satisfactory design decided upon. The design specification for the fuel element assembly line has been completed.

The problem of heat disposal has been studied in detail and alternative systems investigated. The final design follows closely that described in the first annual report.

Primary Circulators.—The intention of having a "Dragon"-designed prototype circulator has been abandoned in view of the limited time available. However, an extensive series of tests in support of the chosen circulator design has been initiated.

A full-scale mock-up of the contractor's (Brown-Boveri) circulator rotor and bearing assembly has been built into a "Dragon" project test rig and is being tested by the project staff in air at atmospheric pressure. Later tests will be done in helium at pressures up to 20 atm. The "Dragon" project is also preparing various test rigs for studying the behaviour of different bearing materials during start-up, run-down, and standstill in helium of the purity specified. These tests will show whether jacking gas has to be provided for the circulators under the conditions mentioned.

Seven of the eight circulators are scheduled for delivery in August, 1962, but the first or prototype has been ordered for November, 1961. It will be installed, together with the prototype heat exchanger, in a test loop which is being built by the "Dragon" project at Winfrith. The proposed programme will include endurance tests on the circulator and aerodynamic tests on the heat exchanger (excluding heat transfer tests).

The drive circuit for the control rod gear box has been designed, and a prototype of a reactor standard control rod drive has been manufactured and will be tested as a complete system in the near future. The length of the control rod has been increased so as to improve its control characteristics.

Various changes have been made with regard to the electrical power supply for the variable frequency generating sets, and the various emergency supplies have been completely defined and specified. Most of the nuclear and process instrumentation requirements have also been decided upon.

The overall design of the charge machine has been completed and manufacture has begun. Apart from certain simplifications which have been incorporated in order to improve the reliability of the machine by canning and decanning the fuel elements outside the pressure vessel, no fundamental

changes have been made. The design of the main entry valve and the spike removal tool are now virtually completed.

Considerable progress has been made in the design of the fission product plant. Several major alterations have been made during the past year and although a large part of the plant has been decided a considerable number of details have still to be worked out. The design of a pilot plant has been completed and manufacture is now in hand; delivery is expected in the near future. Various aspects of remote handling and maintenance are being actively considered and design work is progressing. The design of various specialised items, e.g., selector valve, &c., has been decided upon and in a number of cases the manufacture of prototypes or test rigs in support of the reactor design is under way.

The containment and ventilation of the reactor building has been completely finalised and follows closely the scheme described in the first annual report.

Apart from a number of detail changes and a few additional features the main safety principles as described in the first annual report still apply.

Construction work started at the beginning of the year under review and has gone ahead according to programme, except for some relatively unimportant delays.

MAJOR CONTRACTS PLACED 1960–61

Reactor Contracts.—Absorber rod drive for pressure vessels, Société des Forges et Chantiers de la Mediterranee, France. Airlocks and sealing doors for inner containment shell (sub-contract), Harland and Wolff, U.K. Charge/discharge machine for fuel elements, S.E.C.A., Switzerland. 25-ton circular crane, Ateliers Coupé Hugo, France. Design and drawing office work, C. J. Foote and Partners, Ltd., U.K.; Hebron and Medlock, U.K. Inner containment shell, Whessoe Ltd., U.K. Main civil and building work, Turiff Construction Corporation Ltd., U.K. Mechanical services for reactor experiment, Richard Crittall and Co., Ltd., U.K. Opening-up contract for site—civil engineering work, Turiff Construction Corporation, Ltd., U.K. Primary circuit dump tanks, V.O.E.S.T., Austria. Primary gas circulators, Brown Boveri et Cie, Switzerland. Primary heat exchangers, Waagner-Biro A.G., Austria. Prototype thirty-seven way selector valve unit for sampling of coolant scavenge flow, Plessey Nucleonic, Ltd., U.K. Reactor pressure vessel, Mannesmann-Export, G.m.b.H., Germany. Secondary heat exchangers, Waagner-Biro A.G., Austria.

Electrical Equipment.—415V air-break switchgear, English Electric Company, Ltd., U.K. Emergency supply alternator sets, Brush Electrical Engineering Company, Ltd., U.K. 11kV 250MVA switchboard, Reyrolle and Co., Ltd., U.K. Direct current air-break switchboard and associated equipment, Whipp and Bourne, Ltd., U.K. Variable frequency generating sets, Brown Boveri et Cie, Switzerland. Electrical installations, reactor experiment, F. H. Wheeler and Co., Ltd., U.K.

Graphite Components.—Dummy fuel element, Mark I, U.K.A.E.A. Inner reflector, U.K.A.E.A. Outer reflector, U.K.A.E.A. Machining, U.K.A.E.A. Rods for control gear, Morgan Crucible Company, Ltd., U.K.

Other Components:—Static coil hysteresis clutch for charge/discharge machine, Sperry Gyroscope, Ltd., U.K. Structural steelwork for main civil building work (sub-contract), Modern Engineering (Bristol), Ltd., U.K. Temporary cranage for construction, Constructors John Brown, Ltd. U.K. Temporary electrics for construction, T. Clarke and Co., Ltd., U.K. Thermal shield tanks, Head Wrightson (Teesdale), Ltd., U.K. Upper and lower support structures within pressure vessel, N.V. Neratoom, The Netherlands. Upper steel support ring within pressure vessel, Sheppard and Sons, Ltd., U.K.

Research and Development Contracts.—Bearing research in Helium, D. Napier and Sons, Ltd., U.K. Carbide fuel studies, U.K.A.E.A. Fission product technology studies, U.K.A.E.A. Fission product control studies, U.K.A.E.A. Furnaces and brazing units, Balzers High Vacuum, Ltd., Liechtenstein. Pad type gas bearing circulator, Société Rateau, France. Pilot helium purification plant, Comprino N.V., The Netherlands. Rigs for diffusion measurements, BBC-Krupp, Germany. Seven-fuel-element experimental plant, C. A. Parsons and Co., Ltd., U.K. Single-channel high-temperature heat transfer rig, Atomic Energy Commission, Denmark. Study of carbon-uranium-thorium system, C.E.A., France. Use of "Zenith," U.K.A.E.A.

Graphite Studies.—Development of fission product retaining fuel and graphite impregnation, Royal Aircraft Establishment, Farnborough, U.K. Development of high-density graphite, Compagnie Péchiney, France. Development of low-permeability graphite, Compagnie Péchiney, France. Development of impregnated graphite, Hawker Siddeley Nuclear Power Company, Ltd., U.K. H.T.G.C. fuel irradiation rig, Hawker Siddeley Nuclear Power Company, Ltd., U.K.

Irradiation Rigs and Experiments.—Irradiation experiments, hire of space in "Pluto" and "Dido," U.K.A.E.A. Rigs for use in DR3 Risø, Atomic Energy Commission, Denmark. Irradiation experiments in DR3 Risø, Atomic Energy Commission, Denmark. Mass transfer loops for use in BR2 Mol, C.E.N. Mol, Belgium. Irradiation experimentsin BR2 Mol, C.E.N. Mol, Belgium. Fission product loops, A.B. Atomenergi, Sweden. Rig and irradiation experiments, Eid. Institut für Reaktorforschung, Switzerland.

Tests on an "Austerity" Locomotive fitted with a Mechanical Stoker

A series of trials have been carried out by the National Coal Board on an "Austerity" steam locomotive fitted with a mechanical stoker. These trials formed the basis of an interesting report, to which our attention was drawn by Mr. T. E. Green, the Chief Traction Engineer of the N.C.B. It is considered that the enthusiastic co-operation of the manufacturers of the equipment and the Area and colliery engineers in these trials has contributed to an encouraging result from which the N.C.B. hopes to gain a useful measure of economy. The report, slightly abridged, is reproduced below.

THE National Coal Board has a fleet of about 1300 standard gauge locomotives, of which more than 75 per cent are coal-fired, the remainder being mainly diesel units. The circumstances of the last two or three years led to a suspension of the change-over from steam to diesel traction and a good deal of attention has had to be concentrated on obtaining the more efficient operation of steam locomotives, particularly in the light of the Clean Air Act. Many possibilities have been examined to this end and one of the most promising was the use of some form of mechanical stoker. Literature available indicated that this class of equipment had not previously been used on the type of locomotive in use by the N.C.B. and Thomas Hill (Rotherham) Ltd., in collaboration with Messrs. Joshua Bigwood, Ltd., undertook the work of development. One of the Board's 18in 0–6–0 "Austerity" locomotives was selected for trials with the stoker which is shown in Fig. 3.

Tests have been carried out to determine the ability of the stoker equipment to enable the locomotive to carry out its normal duties when fired by a variety of coals; and the conditions of smoke emission under operating conditions when fired by a variety of coals. No attempt has been made to determine the relative fuel consumption under these conditions.

The "Austerity" 0–6–0 locomotive used for the tests was built by Robert Stephenson and Hawthorns, Ltd., and is operated at Orgreave Colliery, No. 1 Area, N.E. Division.

The Hill-Bigwood "Vanguard" stoker equipment comprises a double trough underfeed stoker with maximum coal feed capacity of 1500 lb per hour. Two forced draught fans are connected to the stoker windbox by separate ducts and a twin-cylinder Lister engine drives the fans and coal feed screws during normal service. An electric motor is provided for driving the equipment when lighting up. The engine develops 7½ h.p. at 1500 r.p.m. The retort is fitted in the firebox in place of the normal firebars, but, whilst it is the full width of the firebox, it is smaller in depth, leaving a space at the front end which is filled by close-spaced transverse firebars. Control of the coal feed is by a ten-position lever in the cab which provides equal steps from zero to maximum. The

Fig. 1—Before fitting of mechanical stoker to locomotive when using hand-fired Orgreave doubles

Fig. 2—After fitting mechanical stoker to locomotive using Treeton singles

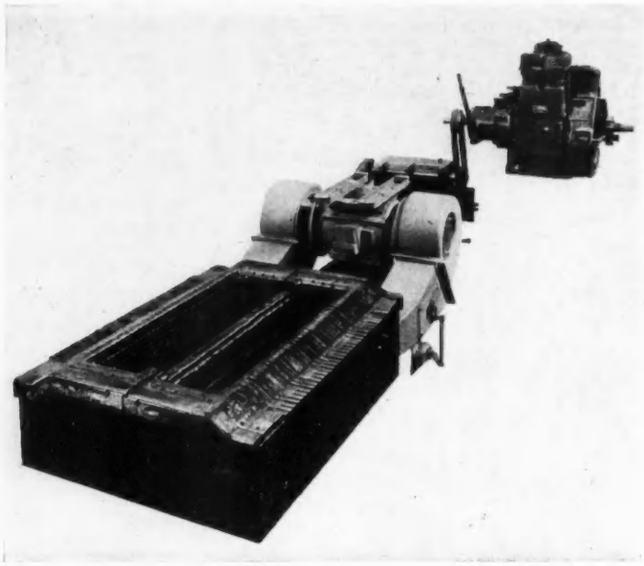


Fig. 3—Mechanical stoker as fitted to "Austerity" locomotive

control of forced draught is by a second lever in the cab which is used to vary the position of dampers, one in each fan duct.

The tests were conducted with the locomotive performing its normal duties, which include the handling of coal traffic from the colliery to British Railways Woodhouse Mill sidings and to the adjacent colliery landsale sidings. These duties include a severe incline of average gradient 1/33, maximum 1/25, about 1100 yards long, with curves. Coal traffic is also handled between the colliery and British Railways Treeton Station sidings and miscellaneous yard shunting work is also involved.

Test Procedure

The locomotive was operated on each type of coal for one day's normal work and observation was kept continuously during the daylight shifts. The following points were noted and recorded :

1. The particular duty and, where appropriate, the load handled.
2. Smoke condition.
3. Boiler pressure.
4. Rate of coal feed.
5. Incidents such as operation of boiler feed injector and opening of safety valve.

The types of coal tested are listed below. The last column indicates the assessment of the Combustion Engineers' Association as to the suitability of the rank for use with underfeed stokers in general, but does not necessarily apply to this type of stoker when used for firing a locomotive.

Test	Source Colliery	Size	Rank No.	C.E.A. assessment
1... ...	National (S.W. Division)	Peas	203	Recommended
2... ...	Orgreave (N.E. Division)	Doubles	501	Not recommended
3... ...	Orgreave (N.E. Division)...	Singles	501	Not recommended
4... ...	Firbeck (N.E. Division)	Singles	601	Recommended
5... ...	Cadeby (N.E. Division)	Singles	602	Recommended
6... ...	Treeton (N.E. Division)	Singles	702	Recommended
7... ...	Hatfield (N.E. Division)	Singles	802	Recommended
8... ...	Bestwood (E.M. Division)	Singles	902	Recommended

The Orgreave coals, although listed as not recommended, were tested because (*a*) Orgreave doubles is the type which was used for the locomotive before fitting the stoker, and (*b*) both are readily available at the colliery.

Results of Tests

Owing to the inherent conditions of normal locomotive operation, (e.g., wide fluctuations of load, variations in the thickness of the firebed, variations in boiler water level and variations in driving technique as between different drivers,) the data collected during the trials and its evaluation is, to a large extent, subjective and not capable of precise measurement. Consequently, the results given below, which represent average conditions throughout each test, have to be read with these facts in mind.

For all duties, except the unusually arduous one of taking full wagons up the incline, no difficulty was experienced with any of the coals tested, and the performance of the locomotive could be regarded as excellent. For the exceptional duty, the variable factors mentioned above, in addition to the qualities of the various coals, had an influence on the performance.

Prior to the conversion of the locomotive to mechanical firing, a test of one week's duration was carried out using the normal type of coal (Orgreave doubles) during which it was noted that it was not invariably possible to ensure a successful run up the incline. It is against this as a standard that the stoker performance has been assessed.

With stoker firing, it was found that National peas gave a performance at least equal to the standard, whilst the remaining coals gave slightly inferior performances, in the following descending order :

Cadeby singles
Firbeck singles
Treeton singles
Hatfield singles } Equal
Bestwood singles
Orgreave singles
Orgreave doubles

It is likely that further development of the equipment and more experience in its operation will result in marked improvement for this duty.

Smoke Emission

Emission of smoke was generally small. With coking coals it was necessary to use the rake to break down the large pieces of coke which were formed. It was also necessary, with all coals, to use the rake to avoid the existence of "holes" in the fire, particularly when the firebed was thin. Following raking, the density of smoke was increased, but cleared to normal within a short time. The following table shows average conditions during the test.

Coal used	Smoke density		Time to clear to normal after raking
	General	After raking	
National peas	Smokeless	Medium	20 seconds
Orgreave doubles ..	Smokeless	Dense	30 seconds
Orgreave singles ..	Smokeless	Dense	50 seconds
Firbeck singles	Slight	Dense	50 seconds
Cadeby singles	Slight	Black	70 seconds
Treeton singles	Slight	Dense	60 seconds
Hatfield singles ..	Medium	Black	60 seconds
Bestwood singles ..	Medium	Black	90 seconds

Two of the photographs given in the report show typical smoke conditions and are reproduced in Figs. 1 and 2. The terms used for indication of smoke density have the following meanings : Slight—just visible ; Medium—thin but obvious ; Dense—thick but not black ; and Black—thick and black. The Clean Air Act makes it an offence for a locomotive to emit dark smoke, which is defined as smoke as dark as or darker than Shade 2 on the Ringelmann chart. In the conditions of the tests it was found difficult to correlate the indications of density with the Ringelmann chart, but the term "medium" would correspond approximately to Shade 2, or somewhat lighter.

On this basis, all the coals, with the exception of Hatfield singles and Bestwood singles, would comply with the Act. Even in the case of these doubtful examples, there was operation for lengthy periods with smoke emission no denser than "slight."

Analysis of Coals

Colliery	Size	Rank	BSSW	M	A	V.M.	F.C.	C.V.	S.
Orgreave...	1¼in by 1in	501	7	3·9	5·5	33·4	57·2	13,730	1·78
Orgreave...	1in by ½in...	501	7½	4·8	5·7	33·1	56·4	13,580	1·79
Firbeck	1in by ½in...	601	6	6·1	6·1	32·5	55·3	13,240	1·02
Cadeby	1in by ⅜in...	602	6	6·3	4·0	34·1	55·6	13,460	1·36
Treeton	1¼in round by ½in square	702	5	7·0	4·5	32·8	55·7	13,200	1·80
Hatfield	1in by ½in...	802	2½	9·3	3·6	34·5	52·6	12,790	1·25
Bestwood	1in by ½in...	902	1	16·0	5·5	30·9	47·6	11,040	0·59
National...	½in by ⅜in...	203	—	3·5	5·5	14·8	76·2	14,260	0·75

Conclusions

The tests proved that the locomotive fitted with the underfeed stoker was capable of carrying out its normal duties approximately as well as when hand-fired and, generally, with the emission of little or no smoke. With most of the coals tested, dark smoke was emitted only when the fire was raked, but this persisted only for a very short time. It was also shown that coals not normally recommended for use in underfeed stokers could be used with success. There were indications that there was scope for improvement in the equipment, particularly in the control of the coal feed and combustion air, and also in the technique of operating it, which would improve the performance and reduce still further the smoke emission.

Precise Control of 3000-ton Forging Press.—The staff photographers of firms seldom have their work publicly acknowledged. We are all the happier, therefore, at being able to state that all the colour photographs which were reproduced in last week's issue were taken by Mr. J. A. Thornton, of Davy and United Engineering Company, Ltd., on our behalf.

SHORTER REPORTS

International Conference of Marine Engineers

THE Institute of Marine Engineers is organising an International Conference of Marine Engineers to be held in London from May 7 to 12, 1962. As presently arranged the Conference will be opened by the President on the morning of May 7, followed by a paper on "Operating Experience with S.S. 'Canberra'" by T. W. Bunyan, B.Sc. There will be an official luncheon at the Mansion House, and a paper by R. Frederikson on "Diesel Machinery with Geared or Electric Drive" in the afternoon, and an exhibition of "100 Years of Marine Engineering" at the headquarters of the Institute in the evening. On Tuesday morning, May 8, papers entitled "Post-War Developments and Future Trends of Steam Turbine Tanker Machinery," will be given by representatives of B.P. Tanker Company, Ltd., and John Brown and Co. (Clydebank), Ltd., and another paper having the same title by H. Bauer of the De Laval Steam Turbine Company. Following luncheon at Colonial House, papers on "Direct Drive Diesel Machinery" will be presented by P. Jackson, M.Sc., and by H. Andresen. In the evening a dinner will be held at Grosvenor House. A paper on "Nuclear Propulsion of Ships" will be read on Wednesday morning followed by a river trip to Greenwich and luncheon at the National Maritime Museum, and an evening reception at Guildhall. Various visits will be arranged for Thursday with a reception at Lancaster House in the evening, and on Friday, May 11, visits will be paid to the N.P.L., W. H. Allen Sons and Co., Ltd., the British Internal Combustion Engine Research Association, and Petters, Ltd.

Biggleswade By-Pass

THE Biggleswade by-pass, one of the chain of improvements on the Great North Road (A1), was opened to traffic last week. The by-pass is more than 2½ miles long. It leaves the A1 a ½-mile south of Dunton Turn junction and, running to the south and west of Biggleswade, rejoins the trunk road a ¼-mile north of the Old Warden junction. In addition, from this point northwards for more than 2 miles, the existing road has been improved to the same standard as the by-pass, namely; dual 24ft carriageways, 10ft wide central reservation and hard shoulders. Bridges carry the by-pass over the main King's Cross railway line, Langford Road (A6001) and the River Ivel. The whole scheme, totalling 5 miles in length and costing about £1,000,000, was prepared for the Ministry of Transport by Bedfordshire County Council whose county surveyor is Mr. S. W. Lynn; the contractor was Sydney Green and Sons (Contractors), Ltd.

Oil Industry Statistics

THE *Statistical Review of the World Oil Industry for* 1960 published by The British Petroleum Company, Ltd., indicates that the world proved reserves improved only slightly to 41,010 million tons, while production rose by 7 per cent over the 1959 level to 1079 million tons. The main producing countries were: U.S.A. with 382, Venezuela with 149, Iran with 51, Iraq with 47, Kuwait with 81, Saudi Arabia with 61, and the U.S.S.R. with 146 million tons. World oil consumption increased by 8 per cent, to 1060 million tons, largely as a result of increased demand for heating oils in the Eastern Hemisphere. In spite of growing self sufficiency in some areas the tendency for the proportion of world oil production entering international trade to fall was reversed in 1960, exports totalling 449 million tons. During the year overall expansion in refining capacity lagged behind the growth in oil demand, the total at 1119 million tons being an increase of 5 per cent over 1959 compared with an average of 8 per cent over the last five years; however, for Western Europe the increase in refinery capacity was 13 per cent. According to the review new tanker deliveries dropped to 5,500,000 tons deadweight in 1960, a total which is 1,750,000 tons below the 1959 figure. Tonnage scrapped or converted increased to about 3,000,000 tons, so that at 64,000,000 tons deadweight the fleet showed a net increase of about 5 per cent over 1959. Laid-up tonnage at the end of 1960 was 2,000,000 tons less than at the corresponding date in 1959, but orders placed and under construction declined by about 5,000,000 tons to 14,600,000 tons deadweight at the end of 1960. Energy demand continued to rise and was at a level some 5 per cent higher than in 1959.

Reversible Power Plant for Cruachan Pumped Storage Power Station

ORDERS have been placed for the main pumping and generating plant required by the North of Scotland Hydro-Electric Board for the Cruachan pumped storage power station of the Board's Loch Awe scheme. This 400MW power station will be built underground in the slopes of Ben Cruachan. It will be the largest station in the scheme, which also includes two more orthodox hydro-electric power stations, one at Inverawe and the other at Nant. The idea of the pumped storage station is that during off-peak periods (at night and week-ends) the main machinery will operate as electrically-driven pumps to raise water from Loch Awe to a storage reservoir formed by a dam with a crest more than 1300ft above sea level at the head of the Cruachan burn. At periods of peak electrical demand the functions will be reversed, and the power station plant will operate as hydro-electric generators, using the water stored in the upper reservoir at a head of about 1200ft.

Two of the reversible pump-turbine-generators in Cruachan power station will be supplied by Associated Electrical Industries, Ltd. Each of the electrical machines will be rated at 100MW as generators and 160,000 h.p. as motors. The pump-turbines will be provided by Boving and Co., Ltd. as sub-contractor to A.E.I.

A similar order has been placed with The English Electric Company, Ltd., for two 142,000/136,500 h.p. reversible pump turbines each coupled to a 111MVA motor/generator unit, These sets will be designed by English Electric in collaboration with Sulzer Brothers, and will be made in Scotland by Harland and Wolff.

The consulting engineers for the electrical and mechanical plant are Messrs. Merz and McLellan.

Experimental On-load Fuelling of Calder Hall Reactors

TESTS have been conducted in the Calder Hall reactors to find out what happens when fuel elements are loaded into a reactor on full power. It will be recalled that the C.E.G.B. civil power stations have been designed to allow fuel replacement while the reactors are running continuously and the Calder experiments were to check that the fuel elements would withstand the temperature changes involved.

The Calder reactors were designed for complete fuel changing with the reactors shut down and depressurised. For these tests, therefore, it was necessary to adapt existing charge and discharge equipment to provide on-power fuelling conditions. The element to be tested was suspended from a spare control rod mechanism modified to give the required speed of insertion and to hold the element in the required position in the reactor. The gas flow through the channel was adjusted so that the test element, by virtue of its own heat production and that of the other elements already in the channel, would experience the required temperature changes. This arrangement simulated the actual civil station loading conditions where it is expected that the elements (perhaps after some preheating in the charge machine) will be subjected to a further rapid increase in temperature when inserted into the core.

After the tests the irradiated elements were sent to the laboratories for metallurgical and radiographic examination by remote handling. These tests revealed no significant effects on the elements as a result of on-load charging.

A second experiment was carried out to study the effects of frequent variations in temperature —thermal cycling—on fuel elements. The elements already in a civil reactor would be subject to these changes every time an adjacent channel was charged or discharged. To simulate these changes, two control rods were oscillated up and down in the reactor core to produce temperature variations in the neighbouring channels. The oscillations were continued for approximately 13,000 cycles and the nearby fuel elements then discharged and examined. Again no measurable ill-effects were found.

Ester-Resistant Rubbers

THERE are now offered by Precision Rubbers, Ltd., Bagworth, Leicester, new rubber compounds named "Prescothene" with an enhanced resistance to "Skydrol" non-inflammable hydraulic fluids at high temperatures. These rubbers have been tested in five fluids, namely:

"Skydrol" 500A, phosphate ester base hydraulic fluid

D.E.R.D. 2487, synthetic dicarboxylic acid-ester lubricant

D.E.R.D. 2492, isopropyl nitrate

Lockheed 102 and 103, castor-base hydraulic fluids.

Immersion for ninety-six hours at 170 deg. Cent. in Lockheed 102 leaves "Prescothene" virtually unaffected, but in Lockheed 103 grade X471A gains 9·3 per cent in volume and drops six points in hardness, while grade B373 gains 11·6 per cent and drops 10 points. At 150 deg. in "Skydrol" 500A the order of merit is reversed, B373 growing 8·2 per cent and softening seven points, while X471A grows 10·8 per cent and loses eighteen points. In D.E.R.D. 2487 at 100 deg. Cent. both rubbers swell about 28 per cent and lose twenty-two points. Particular merit is claimed for the retention of strength and elongation in a hot soak, as shown in the Table below.

TABLE—*Ageing Characteristics*

Compound No.	X471A	B373
Original properties :		
Tensile strength, lb per square inch	2,660	2,425
Elongation at break, per cent	370	375
Hardness, B.S. deg. and I.R.H.	65	77
Aged two weeks/100 deg. Cent. in air :		
Tensile strength, lb per square inch	2,130	2,530
Elongation at break, per cent	340	330
Hardness, B.S. deg. and I.R.H.	65	80
180 deg. bend test	Pass	Pass
Aged one week/150 deg. Cent. in air :		
Tensile strength, lb per square inch	1,152	700
Elongation at break per cent	365	300
Hardness, B.S. deg. and I.R.H.	57	84
180 deg. bend test	Pass	Pass
Aged seventy hours/150 deg. Cent. in "Skydrol" 500A :		
Tensile strength, lb per square inch	1,610	2,055
Elongation at break, per cent	315	355
Hardness, B.S. deg. and I.R.H.	54	68
180 deg. bend test	Pass	Pass

It is claimed that corrosion of metals in contact with the rubber has been reduced to be less than with any other rubber compatible with "Skydrol."

[Reply Card No. 1133]

SHORTER REPORTS *(Continued)*

Wye Valley Road Improvement

WORK is to start this month on a scheme costing, in total, about £2,250,000, for improving the road between the western end of the Ross By-pass, and Dixton Church, Monmouthshire, a distance of about 8½ miles, as part of the improved road connections between the Midlands and South Wales, via the Birmingham–Bristol and Ross Motorways.

The general line of the existing Ross–Monmouth road (A.40), will be followed, but the hilly nature of the country has called for unusual and spectacular treatment, the Ministry of Transport states. In places, cuttings, largely in sandstone, will be 22ft deep and embankments up to 40ft high. For ¾mile along the steep hillsides of the Wye Valley, one carriageway will be 30ft above the level of the other. Existing side-roads will be carried over the road at four grade-separated junctions, while the scheme involves three underpasses, six road bridges and a river bridge.

The work will be carried out in three stages. The contract for the first stage, involving 3½ miles of road from Ross By-Pass to Goodrich Cross, has been awarded to the Hadsphaltic Construction Company, Ltd., whose tender amounted to £600,655. Dual 24ft carriageways will be built with a 15ft central reservation and verges generally 12ft wide.

Plans for the second stage—Goodrich Cross to the Monmouthshire boundary—are now nearing completion, and work is expected to start early next year. These sections of the scheme have been prepared for the Minister of Transport by the Herefordshire County Council (County Surveyor, Mr. D. H. Banks). The third stage of the scheme—from the Monmouthshire boundary to Dixton Church—has been prepared by Monmouthshire County Council (county surveyor, Mr. D. W. G. Barren), and work on it should start later this year.

Cook Strait Submarine Power Cable

SUBMARINE gas-filled power cables, supplied by British Insulated Callender's Cables, Ltd., will be used for the power link across the Cook Strait between the North and South Islands of New Zealand. The relevant contract (worth £2,700,000) placed with B.I.C.C. by the New Zealand Electricity Department, Wellington, involves the supply and installation of 76½ statute miles of submarine gas-filled power cables, together with terminations accessories and spares.

The cables will form part of a high-voltage direct-current transmission system between existing power stations in the North and South Islands of New Zealand and will operate at a nominal voltage of ±250kV to earth. Three single core cables will be used ; two of them will form the conductors of the direct-current circuit and the other will be spare. The rated load capacity of the circuit will be 600MW or 1200A.

The cable will be made by British Insulated Callender's (Submarine Cables), Ltd., at Trafford Park, Manchester, and installed by British Insulated Callender's Construction Company, Ltd., both members of the B.I.C.C. Group.

It will be recalled that the future development of the electrical power supply in the North and South Islands and their inter-connection has been under review by the New Zealand Electricity Department for some time. Both islands have a large hydro-electric potential and both have some seasonal surpluses of hydroelectric capacity. The fact these surpluses are not coincident gives rise to the possibility of seasonal two-way transmission of power. A submarine cable power link between the two islands would, therefore, give prospects of a saving in spare generating plant capacity and might enable the supply authority to close down coal burning stations. The technical and economic aspects of this proposition have been studied closely.

In 1956 the New Zealand Government commissioned B.I.C.C. to report on the feasibility of a submarine cable crossing. Two years later B.I.C.C. designed, manufactured and installed

0·85 square inch, single core 250kV, d.c. gas-filled cable for Cook Strait crossing. The cable is paper insulated, lead alloy sheathed, reinforced, tough rubber sheathed, galvanised steel wire armoured and served

in Cook Strait a sea trial length of cable. This cable was recovered in 1960, subjected to exhaustive tests and examined in detail.

The cables which have now been ordered will connect the long high-voltage direct-current overhead transmission lines, which will be erected from Benmore power station on the Waitaki River of the South Island and from Haywards substation, north of Wellington on the North Island. Convertor plant will be installed at Benmore and Haywards for conversion of a.c. to d.c. at one end for transmission by the cable, and for inversion, d.c. to a.c.,at the other. The cables are to be installed and ready for commercial service by April, 1965.

The submarine cable, as used successfully for the trial length (illustrated), is single-core gas-filled cable and will be manufactured without joints in continuous lengths sufficient for the crossing. The 0·80 square inch conductor consists of a spiral steel duct over which are applied four layers of copper wires to form the conductor. Paper tapes impregnated with a compound of mineral jelley are applied over the conductor to form the insulation. The insulation is surrounded by nitrogen gas at 450 lb per square inch and contained within a lead alloy sheath reinforced with steel tapes. The reinforced cable is protected against corrosion by a vulcanised tough rubber sheath, armoured with heavily galvanised steel wires and served overall. The nominal overall diameter of the cable is approximately 5in. Its weight in air is 89·3 lb per yard and in water 63·4 lb per yard. The operating pressure for the gas is 80 lb per square inch higher than the external water pressure at the deepest part of the cable route, which is 139 fathoms. The shore end cables are of similar construction to the submarine cable except that the conductor size is 1·25 square inch and the armour wires are smaller.

The cables will be laid (between Oteranga Bay in the North Island and Fighting Bay in the South Island) in continuous lengths from an ocean going vessel which will be specially adapted for cable laying with machinery manufactured by Telcon (Greenwich), Ltd., a member of the B.I.C.C. Group. This machinery is electro-hydraulically driven and is capable of picking-up 50 tons, and paying-out up to 16 tons at speeds of up to 8 knots. The installation includes the following equipment : holding-back gear to prevent the cable slipping on the 16ft diameter capstan when picking-up or paying-out ; dynamometers to indicate the tension on the cable, length paid out and speed of cable when picking-up or paying-out ; a bell-mouth at the bows to guide the cable when picking-up or paying-out.

The ship that is to be chartered for the cable laying is the M.V. "Photinia," built by John Redhead & Sons, Ltd., for the Stag Line, Ltd. This ship, of 7660 tons gross, length overall 479ft 8in, is designed primarily for rapid handling of bulk cargoes, particularly grain and sugar, and has six square self-trimming holds with hopper sides and no obstructions. She is readily adaptable for laying cables and pipelines and has been chartered for the laying of the "Magna" pipeline, British Columbia—another B.I.C.C. contract, announced in THE ENGINEER, January 13, 1961, page 55—as well as for the Cook Strait power cable, using the machinery described above.

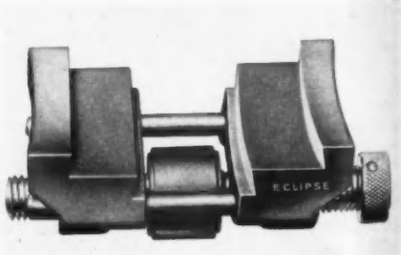
Honing Guide

A NUMBER of guides have been introduced to assist craftsmen and woodworkers in sharpening plane irons and chisels to the correct cutting angles, and we illustrate a recent addition to this class of tool introduced by James Neill and Co. (Sheffield), Ltd., Sheffield, 11. This "Eclipse" honing guide is of self-centring and self-aligning design, and in tests we have found the tool easy to use and to produce accurate cutting angles on irons and chisels when the simple setting instructions are followed.

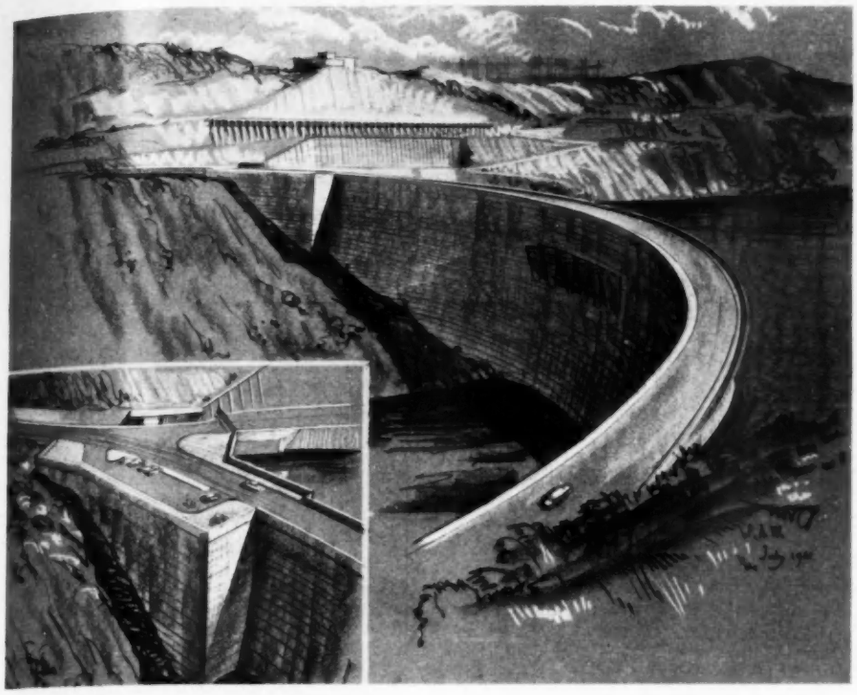
The guide consists of a pair of stepped self-centring jaws mounted on parallel bar guides and operated by a single screw with a knurled head. During the honing or sharpening operation a straight faced hardened steel roller on the screw supports the guide and holds the tool squarely on the stone whilst allowing a free movement of the tool along the stone.

Plane irons up to 2⅜in wide are held between the wide steps of the jaws and the narrower steps are used for holding chisels up to 1⅛in wide. Chisels up to ¼in wide are placed on the bar guides between the jaws and gripped between the lower parts of their bodies. The right-hand jaw faces are curved to ensure that tools are held firmly, and both sets of jaws have undercut faces to prevent a tool lifting during honing. To produce the correct cutting angle tools are clamped with their edges a given distance from the front faces of the jaws. Instructions supplied give the setting distances to produce the standard cutting angles on plane irons and chisels.

[Reply Card No. 1127]



Self-centring, self-aligning honing guide for plane irons and chisels



Artist's sketch of Kariba Dam, showing block to be built at left bank abutment

Abutment Strengthening at Kariba Dam

LAST week, the chairman of the Federal Power Board of Rhodesia and Nyasaland, Mr. E. Ward, held a press conference in Salisbury, which was widely reported in the daily press. He announced that further work was to be undertaken at Kariba dam to strengthen the upper zone of the left bank abutment.

The works required are quite extensive ; it was reported that they will take fourteen months to complete and will involve the placing of 70,000 cubic yards of concrete, half of it underground and half above ground, together with 25,000 cubic yards of what is termed "rock filler." The following statement on this work comes from the British consultants concerned with the civil engineering works at Kariba, Sir Alexander Gibb and Partners :

"As a result of more intensive exploration and further testing of the condition of the rock on the upper part of the South flank of Kariba dam, the Federal Power Board is considering the construction of a heavy abutment block on the good quality rock on which the rest of the dam is built.

"It was always recognised that rock treatment of a relatively small zone of weaker quartzite in the top part of the South flank would be necessary. In view of the tight construction programme required for the early production of power, it was decided that any necessary work could safely be postponed.

"In the last eighteen months work has proceeded in strengthening the quartzite zone. Some of the weaker rock, known as mica schist, has been removed and replaced with concrete. Other parts of the rock have been treated by grouting. This work has strengthened the rock mass considerably. But recent checking by the most modern seismic and other test equipment has shown that substantial further strengthening is necessary to ensure that the south abutment is completely reliable when it is called upon to carry the full water pressure at the very top level of the reservoir. This level will not be reached for another year or two.

"The Board's consulting civil engineers have recommended that the best way of achieving this strengthening is by providing a gravity block to transfer thrust from the quartzite to the sound biotite gneiss on which the remainder of the dam is solidly and securely built. Such an abutment block is commonly used in the building of concrete arch dams.

"The abutment block will require approximately 100,000 cubic yards of concrete as compared with the total amount of concrete in the dam itself of approximately 1,250,000 cubic yards.

"The final cost of the scheme will still show a saving on the estimated cost of £79,500,000 for the first stage of the Kariba project prepared in December, 1955. In addition the project as built provides a dam 20ft higher than originally intended, an extra 100,000kW generator and an extra 330,000V substation, none of which were provided for in the original estimate.

"The work on the abutment block will be carried out gradually at an economical rate with the minimum of inconvenience to the public using the road over the dam. During the same period the Federal Power Board will be changing two machines from low level to high level intakes. These temporary low level intakes were used to enable power to be produced at the beginning of 1960 while the Lake was filling."

A description of the Kariba scheme was published in THE ENGINEER of May 13, 1960, pages 806–812.

Swing Bridge at Stepney

A NEW swing bridge built for British Waterways and the London County Council to carry Narrow Street, Stepney, over the ship-lock entrance to Regent's Canal Dock, was opened last week. The bridge, which is 135ft long and 32ft wide, is designed for two lanes of traffic and weighs about 400 tons.

It is controlled from a nearby tower and the whole operation from flashing the warning lights to the opening of the lock for shipping takes less than two minutes.

To overcome transport problems, particularly on the busy roads leading to the bridge site, the consulting engineers designed the bridge as an airtight steel box and had it floated from the contractor's Tees-side works down the east coast and up the River Thames to the dock entrance—a journey of forty-seven hours. The whole structure was lifted into position by Port of London wreck-lighters.

The following data are for the swing span :

Unequal arms, approximately 176 ton c.i. kentledge for balancing	
Length on centre line ..	134ft 10½in
Total weight of steel ...	Approximately 180 tons
Width of carriageway...	20ft
Width of footways (two)	6ft
Swinging weight	417 tons
Tail end radius	40ft
Overall width	32ft 11½in
Maximum depth of section	5ft 6½in

The main structure is a "floatable" box-construction with footways carried on cantilever brackets attached with grip bolts. The main box has four web plates with stiffened bottom plate and battledeck top plate with top and bottom cross-girders and vertical stiffeners, and is all welded. All external surfaces were grit-blasted and metal sprayed prior to painting ; the carriageway and footways are coated with about 1½in of asphalt.

The bridge was fabricated completely in the shops, all work, consequently, being done under cover. Spot radiographs were taken of the main welds and inspection was carried out by Lloyds. The bridge is mounted on a fabricated pedestal which houses a Skefko spherical roller bearing. The swinging weight is transmitted through top and bottom pivot blocks with spherical seats to this bearing. There are two tail rollers and two balancing rollers, each of which is fitted with spherical bearings. On completion the bridge was traversed out of the shop on bogies and placed on a turntable. It was then turned through approximately 90 deg. and jacked on to one of the slipways.

The bridge was designed by Husband and Co., consulting engineers, to the requirements of Mr. V. H. Tripp, principal engineer, British Waterways, and Mr. Joseph Rawlinson, chief engineer, London County Council. Head Wrightson (Teesdale), Ltd., was the main contractor ; the machinery was supplied by Sir William Arrol and Co., Ltd., and foundations were undertaken by W. and C. French, Ltd.

Swing bridge at Stepney

INDUSTRIAL NEWS

Employment and Unemployment

According to the latest statistics published by the Ministry of Labour, the number of people in civil employment in Great Britain during June is estimated to have increased by 54,000 to 23,865,000. There was little change in employment in manufacturing industries as a whole. The number of people employed in shipbuilding and marine engineering dropped by 3000 and in the metal manufacturing industries by 2000, whilst the number employed in the the engineering and electrical goods group increased by 1000.

In the week ended June 24, 1961, the Ministry says, the estimated number of operatives working overtime in establishments with eleven or more employed in manufacturing industries, excluding shipbuilding and ship-repairing, was 1,982,000, each working eight hours' overtime on average. This estimate was 159,000 more than at the end of May. In the same week, the estimated number of people on short-time in these establishments was 42,000, each losing 12½ hours on average. This estimate was 6000 more than at the end of May.

The final unemployment figures for Great Britain at July 10 show little change from the provisional figures announced on July 20. The total of 258,550 included 34,985 married women and 4966 school leavers. The number of persons unemployed for more than eight weeks was 136,364, which was 55 per cent of the wholly unemployed. During the period June 12 to July 10 unemployment fell in most industries and services. There was a reduction of 4600 in manufacturing industries. As is normal at this time of the year, the Ministry points out, there was an increase in the number of boys and girls not previously in employment registered as unemployed on leaving school. The decreases between June and July in the numbers wholly unemployed were less than the normal seasonal movement, particularly in the manufacturing and construction industries.

Between June 8 and July 5 there were increases in the number of unfilled vacancies in most industries and services. The overall increase of 12,000, which was mainly in the manufacturing industries, was the result of an increase of 14,000 in vacancies for boys and girls and a decrease of 2000 adult vacancies.

Safety Regulations

A safety code for workers exposed to ionising radiations in industry is laid down in the Ionising Radiations (Sealed Sources) Regulations, 1961, made by the Minister of of Labour, Mr. John Hare, and presented to Parliament last Thursday, August 3. Most of the requirements will come into operation in six months' time, but those requiring the notification of the use and disuse of ionising radiations in factories will be effective from Tuesday, August 15.

The regulations impose requirements for safeguarding the health and safety of persons employed in factories and other places to which the Factories Acts apply, who may be exposed to ionising radiations from sealed radioactive substances, and from certain machines, such as X-ray apparatus. They require the restriction of the exposure of workers to such radiations, the adequate shielding of sources of ionising radiations, and instructions for workers likely to be exposed to them about the hazards involved and the precautions to be taken.

Maximum permissible doses of radiation are laid down, and the regulations include requirements for the medical supervision of workers, and for the wearing of film badges to measure personal doses received.

The regulations have been drawn up in the light of numerous observations received after the publication of two preliminary draughts and two statutory draughts, and of consultations with organisations of employers, workers and other interested parties. They were also considered by an *ad hoc* expert committee appointed to advise the Chief of Inspector of Factories on the subject, by the Advisory Panel on Radiological Problems in Industry and by the General Purposes Committee of the Radioactive Substances Advisory Committee.

Wages and Costs

In a statement issued last Friday the British Employers' Confederation warns that Britain's entry into the Common Market, if it takes place, will make radical changes in the climate of collective bargaining and of the attitude of employers towards practices which impede productivity.

A major advantage in collective bargaining, the Confederation says, is that it offsets the very real risk of a trade union playing off one employer against another. A disadvantage is that employers are less sensitive to increases in rates than they would otherwise be because competing companies, manufacturing substantially similar products, are all subject to the same rise in labour rates and therefore the products of one company have not suffered from the rise in relation to those of another company. With the Common Market in operation a company manufacturing in Great Britain will be in direct competition at home and in continental markets with an overseas company whose costs will not be affected by any increase negotiated in Britain.

Wage Claims

Despite the announcement made by the Chancellor of the Exchequer in the "July Budget" (THE ENGINEER, July 28, 1961) "..that increases in incomes must follow and not precede or outstrip increases in national productivity," many unions are continuing to advance claims for extra pay and a shorter working week. The Confederation of Shipbuilding and Engineering Unions has lodged claims on behalf of more than 3,000,000 engineering and shipbuilding workers for an increase in pay coupled with a reduction in hours from the present forty-two hour week to a forty-hour week.

The National Union of Mineworkers has stated that it intends to press forward with a wage claim for some 300,000 daywage workers in the coal industry in spite of the Government's appeals. Its negotiating committee will prepare the claim for endorsement by the executive of the National Union of Mineworkers on September 14 and it will then be presented to the National Coal Board. The Post Office Engineering Union pay claim has been the subject of negotiation with the Post Office for some months, and a three-week ban on overtime by the union's 73,000 members began on Tuesday this week in protest at the continuing deadlock. The National Union of Railwaymen has decided to continue with its wage claim, which is due to be discussed with the British Transport Commission on August 21. The executive of the National Union of Agricultural Workers announced on July 28 that it had "unanimously decided to prosecute a claim for an increase in wages and a reduction in hours, notice of which was given to the Central Agricultural Wages Board for England and Wales at the beginning of this month."

The General Council of the Trades Union Congress issued a statement the day after the Chancellor's announcement in which it said that it was surprising that the Chancellor should propose a pause in wage increases until productivity had caught up, as the rise in industrial output during the last two years had far exceeded the rise in rates of wages.

Fire Research in 1960

According to the figures given in the 1960 report of the Joint Fire Research Organisation published last Friday, fire brigades in the United Kingdom attended about 133,000 fires during the year. The cost of these fires has been estimated at some £44,000,000. The Organisation has carried out periodic studies of the occurrence of fire in dwellings built since the war, to see whether new materials and methods of construction were affecting the fire hazard of dwellings. The findings, covering the years 1947 to 1956, show that the rate of incidence of fires in temporary dwellings has been increasing, and by the end of 1956 it had attained a level of 19·3 per 10,000 dwellings at risk per year, compared with sixteen for dwellings of all types, both post-war and pre-war. Permanent non-traditional dwellings, however, have a better fire record, the rate of incidence of fires between 1953 and 1956 being only eight per 10,000 at risk.

During the year, the report states, a study has been made of the reports of fires associated with electrical supply installations, and it was found that 65 per cent of these fires were due to failure of fixed cable or flex. About 6 per cent of the fires in wire and cable were attributed to overloading and about 72 per cent to broken insulation resulting from mechanical causes, moisture, heat, chemicals or age.

The Organisation is collecting and analysing information about the hazards of oil burning appliances, but the work is not yet complete. An interim study of 1959 fire brigade reports, however, shows that fires associated with oil burning appliances have continued to increase, there being 5442 in 1959 compared with 3412 in 1956.

Since July, 1960, the work of testing the explosibility of industrial dust clouds has been transferred from the Safety in Mines Research Establishment to the Joint Fire Research Organisation, and during the year forty-one samples of dust have been tested, analysed and classified according to their ease of ignition.

PERSONAL AND BUSINESS

Appointments

MR. T. O. THOMAS has been appointed general manager of the International Division of U.S. Industries, Inc.

THE RIGHT HON. THE EARL OF HALSBURY has been elected President of the Machine Tool Industry Research Association.

MR. P. H. REYNOLDS has joined J.D. Tractors, Ltd., Windsor, as area sales manager for west and central London and Middlesex.

MR. M. J. BAKER has been appointed sales manager, The Power Petroleum Company, Ltd., at its London Head Office, where he has been group manager since 1953.

MR. J. F. SUMMERFIELD and MR. D. G. LAMBERT have joined J. A. Hemming, Ltd., bright steel stockholders of Birmingham and Oldbury, as additional members of its outside sales staff.

THE GEORGE COHEN 600 GROUP, Ltd., has appointed Mr. Peter Bonner, A.M.I.Mech.E., A.M.I.Prod.E., to the board of its associate company, T. C. Jones & Co., Ltd.

MONKS AND CRANE, Ltd., has announced that Mr. R. K. Pridham, southern area manager, and Mr. P. W. Gudgeon, northern area manager, have both been appointed to the board of directors.

THE UNITED STEEL COMPANIES, Ltd., announces that Mr. N. D. Macdonald, general works manager of its Workington Iron and Steel Company branch, has been appointed a director of that branch from August 1.

THE COUNCILS OF THE UNIVERSITY OF MANCHESTER AND THE MANCHESTER COLLEGE OF SCIENCE AND TECHNOLOGY have appointed Mr. Ronald Beresford Dew as visiting professor of Industrial Administration in the Faculty of Technology.

MR. G. ESSAME, at present the staff director of the West Midlands Divisional Board, has been appointed Principal of the National Coal Board's Staff College at Chalfont St. Giles in succession to Mr. N. G. Fisher, whose resignation was announced some time ago.

LONDON TRANSPORT announces that Mr. L. A. M. Ginger, M.I.E.E., A.M.I.Mech.E., assistant chief electrical engineer, has been appointed chief electrical engineer as from September 4 next, to succeed Mr. T. S. Pick, M.I.E.E., M.Inst.F., who is retiring after thirty-eight years' service.

MR. ROBERT J. HUGHES has been appointed chief editor of the training systems division of U.S. Industries, Inc. (Great Britain), Ltd. He will be responsible for setting up the first European programming department for U.S.I.'s newly-introduced teaching machine, the Mark II "AutoTutor."

MR. H. J. WENBAN will relinquish his position as managing director of the Forgrove Machinery Company, Ltd., Dewsbury Road, Leeds, from September 30. He will continue to act as chairman of the board. Mr. W. A. B. Brown has been appointed to succeed him as managing director.

THE BRITISH BROADCASTING CORPORATION has announced the appointment of Mr. R. J. Keir, A.M.I.E.E., as engineer-in-charge of the external services short-wave transmitting station at Skelton, Cumberland, in succession to Mr. H. F. Bowden, Assoc.I.E.E., who retires this month after thirty-six years service.

PROFESSOR VICTOR F. WEISSKOPF, who joined CERN in September last year as member of the Directorate responsible for research, became the fourth Director-General of the organisation on August 1. He succeeded Dr. J. B. Adams, who returns to the United Kingdom as director of the Controlled Thermonuclear Research Establishment at Culham.

Business Announcements

MIDLAND SILICONES, Ltd., has moved its Birmingham sales offices to Lichfield House, Smallbrook, Ringway, Birmingham, 5.

THE PLYWOOD MANUFACTURERS ASSOCIATION OF BRITISH COLUMBIA has opened a new office at 20, North John Street, Liverpool, 2, Lancs. (telephone, Maritime 2639).

IMPERIAL CHEMICAL INDUSTRIES, Ltd., Imperial Chemical House, Millbank, London, S.W.1, has reduced the prices of "Alkathene," its brand of polythene, by 3d.-4d. per lb depending on the grade.

SERCK, Ltd., Birmingham, and the Jamesbury Corporation, Worcester, Massachusetts, have formed a new company, Jamesbury-Serck, Ltd., Eastern Avenue, Gloucester, to manufacture and market the Jamesbury "Double Seal" ball valve.

WILKINSON RUBBER LINATEX, Ltd., Camberley, Surrey, announces that it has arranged to manufacture a comprehensive range of Linatex handwheel, motorised and pneumatically operated valves and a subsidiary range of non-return and safety/relief valves.

COURTAULDS, Ltd., 16, St. Martin's-le-Grand, London, E.C.1, and UNITED MERCHANTS AND MANUFACTURERS, INC. of New York announce a joint venture for the manufacture and marketing in the United Kingdom of glass fibres and fabrics for industrial and decorative purposes.

ASSOCIATED BRITISH CONSULTANTS, Ltd., 195-199, Great Portland Street, London, W.1, announces the establishment of a branch office in Chittagong, East Pakistan. This office will be in charge of Mr. Raymond Durrant, A.R.I.B.A., assisted by Mr. John Bunge, and will undertake planning, design and supervision of construction in that area.

ULTRA ELECTRONICS, Ltd., announces that it has reached provisional agreement with K.G. (Holdings), Ltd. to acquire for cash the entire share capital of its subsidiary W.S. Electronics, Ltd. for the sum of £125,000 approximately, the effective date of purchase to be July 31, 1961. It is the intention of Ultra Electronics, Ltd. to continue the business of W.S. Electronics, Ltd. as a separate entity within the group.

ELLIOTT-AUTOMATION, Ltd., 34, Portland Place, London, W.1, announces that as a part of its policy of expanding its export business, it has created a new directorate of overseas operations. The Group has ten operating subsidiary companies overseas, and over a wide field of its operations exports more than one third of its products. It is also announced that Mr. Keith Newlands, lately sales director of Cossor Radar and Electronics, Ltd., has been appointed director of overseas operations.

ALFRED HERBERT, Ltd., has taken over the whole of the issued share capital of William Whiteley and Sons, Ltd., of Huddersfield. For some years, Alfred Herbert, Ltd., acted as selling agents for certain Witeley products, and this led to a close and growing association between the two companies. This association so developed that it was agreed between the two companies that it would be in the interests of both if the production and selling were integrated. Mr. J. Charlesworth will remain as director and general manager of William Whiteley and Sons, Ltd., and production in Huddersfield will be continued.

IMPERIAL CHEMICAL INDUSTRIES, Ltd., Imperial Chemical House, Millbank, London, S.W.1, and E. S. & A. ROBINSON (HOLDINGS), Ltd., Bristol, are entering into an association to develop the uses of plastic films in the packaging industry. I.C.I. is subscribing for a minority interest in a new Robinson subsidiary to be called Robinson Plastic Films, Ltd., which, together with other Robinson subsidiaries, will manufacture a wide range of plastic film products for the packaging industry. Robinsons is acquiring a minority interest in British Visqueen, Ltd., which is an I.C.I. subsidiary undertaking the manufacture and conversion of polythene and other plastic films.

SMALL AND PARKES, Ltd., Hendham Vale Works, Manchester, 9, and WILLIAM KENYON AND PLATTS (NARROW FABRICS), Ltd., Dukinfield, Cheshire, jointly announce that they have completed a manufacturing and marketing arrangement. The Small and Parkes narrow fabrics department will be merged with William Kenyon and Platts (Narrow Fabrics), Ltd., as from August 26, 1961. Also included in the merger is the patented nylon bonded tape process and service hitherto undertaken by another Kenyon Company, William Kenyon and Sons (Synthetic Fibres), Ltd., under the registered trade mark of "Kennylbond." The re-formed Company, to be known as William Kenyon Platt and Parkes, Ltd., will operate from Railway Street, Dukinfield, Cheshire.

F. PRATT AND CO., Ltd., Halifax, Yorkshire, has been reconstituted as a holding company under the name F. Pratt Engineering Corporation, Ltd. A new wholly-owned subsidiary has been formed to carry on the manufacture and marketing of the existing company's products, under the same name. The directors of F. Pratt Engineering Corporation, Ltd., are: Mr. G. K. Galliers-Pratt, chairman, Mr. A. M. G. Galliers-Pratt, vice-chairman, Miss F. M. Buckley, and Mr. C. H. Harmer. Directors of F. Pratt and Co., Ltd., the trading subsidiary, are Mr. G. K. Galliers-Pratt, chairman, Mr. A. M. G. Galliers-Pratt, vice-chairman, Miss F. M. Buckley, Mr. J. R. Tracy and Mr. G. Mitchell. Mr. A. M. G. Galliers-Pratt has relinquished his position as managing director of F. Burnerd and Co., Ltd., another wholly-owned subsidiary, but remains a member of the board. Mr. J. R. Tracy is the new managing director.

S. SMITH AND SONS (ENGLAND), Ltd., announces that at midnight on August 6, 1961, two new divisions will come into being—the aviation division and the Kelvin Hughes division. The new divisions will be concerned respectively with the aviation and marine businesses previously carried on by several companies in the Smiths Group. The undertakings of the aviation and marine subsidiaries (including Kelvin and Hughes, Ltd.) will, on August 6, 1961, be transferred to S. Smith and Sons (England), Ltd. This step marks the second stage in the integration programme initiated last year with the formation of Smiths industrial division. As in the case of Smiths industrial division, Mr. Ralph Gordon-Smith is chairman of the aviation and Kelvin Hughes divisional boards. Mr. L. A. Morgan is general manager of the aviation division. Deputy chairman of the Kelvin Hughes division is Mr. G. S. Sturrock and Mr. F. W. Bates is general manager. Headquarters of the new aviation division will be Kelvin House, Wembley Park Drive, Wembley, Middlesex. The new Kelvin Hughes division will have its administrative headquarters at New North Road, Barkingside, Essex, and sales headquarters at St. Clare House, Minories, London, E.C.3.

THE WELLMAN SMITH OWEN ENGINEERING CORPORATION, Ltd., announces that due to the expansion of its activities it has decided to segregate and operate the sales organisations of its divisions dealing respectively with cranes and mechanical handling equipment and rolling mill equipment as separate subsidiary companies under the titles of Wellman Crane and Machine Company, Ltd., and Wellman Rolling Mills, Ltd., both of Parnell House, Wilton Road, London, S.W.1. Mr. J. N. Rees, general sales manager (mechanical division) of the Corporation, has been appointed managing director of Wellman Crane and Machine Company, Ltd., the board of which also includes Mr. V. Bellingham, Mr. D. E. Pope, Mr. J. H. Knight, Mr. W. R. Robertson, Mr. S. W. Taylor and Mr. E. H. Dickson. The board of Wellman Rolling Mills, Ltd. will consist of Mr. Cyril Brooks (managing director), Mr. V. Bellingham, Mr. G. W. Clamp, Mr. R. Curdie, Mr. D. H. Goodreid, Mr. R. C. Lees and Mr. A. V. McCumiskey.

Contracts

THE ALDERTON CONSTRUCTION COMPANY, Ltd., has received a contract at a price of £154,742 4s. 5d. for a further stage of the L.C.C. road improvement scheme at the Elephant and Castle, comprising the construction of the eastern portion of the large roundabout, the reconstruction of part of the connecting roads (New Kent Road as far as the railway viaduct and Newington Causeway as far as Rockingham Street) and the construction of two pedestrian subways.

FAIREY AIR SURVEYS, Ltd., has been awarded a contract worth £250,000 by the East Pakistan Water and Power Development Authority. It provides for the aerial photography and mapping of the Western area of East Pakistan where agricultural production is regularly imperilled first by flooding (after the monsoon season) and then by drought during the dry season. The maps will provide new bases for planning drainage and irrigation schemes. The area is one of the most densely populated rural areas in the world, with an average of more than 920 people per square mile. The survey will start in November, 1961, and the operation should be completed by the end of 1963. An important feature of the survey will be the interpolation of 1ft contours within a close framework of photogrammetric spot heights.

Awards

THE LEVERHULME TRUSTEES, in consultation with The Council of Industrial Design and the Society of Industrial Artists, have instituted an annual award for industrial design. Students at art schools and colleges in Great Britain who are engaged in full time courses leading to a recognised diploma in industrial design (engineering) will be eligible. Each school providing such courses will be asked to submit the work of one final year student for adjudication, the work to include two design projects carried to a reasonable stage of completion. The Leverhulme Trust, the Council of Industrial Design and the Society of Industrial Artists, will each appoint one juror to the adjudicating panel. The first award, to the value of £500, will be made in 1962 and is intended for study in Europe, for a period of not less than ten months.

TABLE I—Data for Roselend Scheme

Roselend Dam :

Maximum height of main arch, deepest foundation to crest ...	150m
Developed length of crest of dam...	804m
Volume of concrete in the dam ...	930,000 cubic metres
Volume of excavation	130,000 cubic metres
Surface area of reservoir	320 hectares
Capacity of reservoir	187×10^6 cubic metres
Approximate crest length of arch section of dam (not developed)...	210m
Volume of concrete in arch	466,000 cubic metres
Number of buttresses	Thirty-two
Scour culverts at centre of arch :	
Number of culverts	Two
Diameter of each	1·5m
Centre-line level	1432·5m
Upstream side :	
R.C. screen	15cm openings ; design load 10 tons per square metre
Stoplogs	Operable at 1445m reservoir level
Downstream side :	
Butterfly (guard) valve	1·7m diameter
Hollow jet (operating) valve ...	1·3m diameter
Capacity of culvert	45 cumecs

St. Guérin Dam :

Maximum height above foundations	70m
Height of arch section above foundation block	54m
Thickness of arch at crest	3·1m
Developed length of crest	250m
Radius of arch at crest	116·66m
Theoretical thickness of key section at 1500m level (i.e. the base of the arch proper)...	12m
Volume of concrete	65,000 cubic metres
Scour culverts :	
Number	Two
Type	As at main dam
Capacity of each...	12·5 cumecs

Gittaz Dam :

Maximum height above foundations	95m
Developed length of crest	240m
Volume of concrete	100,000 cubic metres

Les Sauces Power Station :

Gross head available (i.e. between Gittaz and Roselend reservoirs)	About 100m
Installed capacity	18·5MW
Annual output	50×10^6kWh

Intake :

Intake level	1437m
Size of intake screen	19m by 5m
Intake valves :	
Number	Two (in series)
Type	Butterfly
Diameter	3·5m

Pressure Tunnel :

Length	12,600m
Internal diameter	4·4m to 4·2m
Nominal thickness of concrete lining (in sound rock)	20cm to 30cm
Capacity	50 cumecs
Static head :	
Upstream	130m
Downstream	150m
Length of tunnel which is steel lined	Approx. 1100m

Surge Shaft and Penstock—See Part II.

Main Features :

Installed capacity	501MW
Annual output of power	1000×10^6kWh
Gross head	1203m
Rated flow	50 cumecs
Storage capacity	240×10^6 cubic metres

Storage and Hydrology :

Capacity of main reservoir	187×10^6 cubic metres
Top water level	1557m a.s.l.
Capacity of St. Guérin reservoir ...	13×10^6 cubic metres
Top water level	1557·5m a.s.l.
Capacity of Gittaz reservoir ...	40×10^6 cubic metres
Top water level	1595m a.s.l.
Catchments draining naturally to :	
St. Guérin reservoir :	
Pontcellamont	44 square kilometres
Roselend reservoir :	
Doron de Roselend and Treicol torrent	19 square kilometres
Other catchments diverted to reservoir or pressure tunnel : total...	197 square kilometres
Upstream catchwater system :	
Length of tunnel...	25km
Capacity	21 cumecs
Concrete pipes	Several kilometres
Chapieux siphon :	
Length	830m
Diameter	2·1m
Capacity	15 cumecs
Number of intakes	Thirteen
Levels of intakes	Between 1750 and 1600m
Catchment tapped	142 square kilometres
Catchment draining to Gittaz reservoir	11 square kilometres
Ormente catchwater system :	
Length of tunnel	8km
Number of intakes	Three
Catchment tapped	29 square kilometres
Argentine catchwater system :	
Number of intakes	Two
Catchment tapped	5 square kilometres
Bénétan catchwater system :	
Number of intakes	Four
Catchment tapped	10 square kilometres
Annual flow for power in the mean year from all catchments ...	385×10^6 cubic metres
Storage capacity as percentage of annual inflow	62·3 per cent

Organisations responsible for the Scheme:

Design and supervision of construction	Région d'Equipement Hydrauliques Alpes 11, of Eléctricité de France
Consultants for dam	Messrs. Coyne & Bellier
Contractors :	
Main civil engineering consortia :	Groupement d'Entreprises du Barrage de Roselend ; Groupement d'Entreprises de la Bathie
Pressure tunnel, &c....	l'Entreprise Borie
Penstock	Société Bouchayer et Viallet
Turbines	Etps Neyrpic
Alternators...	Jeumont–S.W.
Transformers	Société Savoisienne
Electrical work at power station	" S.L.E.–C.G.E.E."

Power Station :

Main generating sets :	
Number and capacity	6 × 83·5MW
Type	Vertical-shaft Pelton-wheel-driven
Operating speed	428 r.p.m.
Generation at	10·3kV, 50 c/s
Turbines	One runner, two jets per set
Weight of runner	23 tonnes
Alternator : capacity	88MVA at p.f. =0·93
Weight of rotating parts of set ...	220 tonnes
Clearance between top of set and hook of e.o.t. crane	5·4m
Transformers :	
10·3/380kV	4 × 88MVA
10·3/220kV	2 × 88MVA
Power for auxiliaries (i)	45kV local grid
(ii)	Pelton - wheel - driven set 1·4MVA, 5·5kV
E.O.T. Cranes :	
Machine hall	Two × 100 tonnes with 10-tonne hooks
Valve hall	One × 40 tonnes
Principal dimensions :	
Machine hall :	
Length	130m
Breadth	25m
Height to crown of arch... ...	132m
Tail race :	
Length in tunnel	150m
Length in canal	660m
Total excavation for power station complex	130,000 cubic metres

Summary of water control upstream of turbine jets :

Intake at Roselend reservoir... ...	Two 3·5m butterfly valve in series
Immediately downstream of surge shaft	One 3·5m butterfly valve
(Note : Control of these valves which are at each end of the pressure tunnel is linked to avoid damaging hydraulic conditions in the tunnel.)	
At power station valve chamber ...	Two 1·25m diameter spherical valves in series controlling flow to each set

Principal Constructional Quantities for Entire Scheme (excluding Gittaz dam and Les Sauces power station which are not yet built) :

Length of tunnels, adits and shafts including shafts	61km 500m
including tunnels sloping at 70 per cent	1350m
Total volume of excavation	900,000 cubic metres
Volume of concrete :	
Surface	1,040,000 cubic metres
Underground	280,000 cubic metres
Total	1,320,000 cubic metres
Weights of steel and plant in permanent work :	
Steel in penstock and tunnel lining...	10,000 tonnes
Turbines	1,000 tonnes
Alternators	2,100 tonnes
Transformers	1,000 tonnes
Other plant	1,200 tonnes
Total	51,300 tonnes
Steel used as shoring, &c., in tunnelling	6,000 tonnes

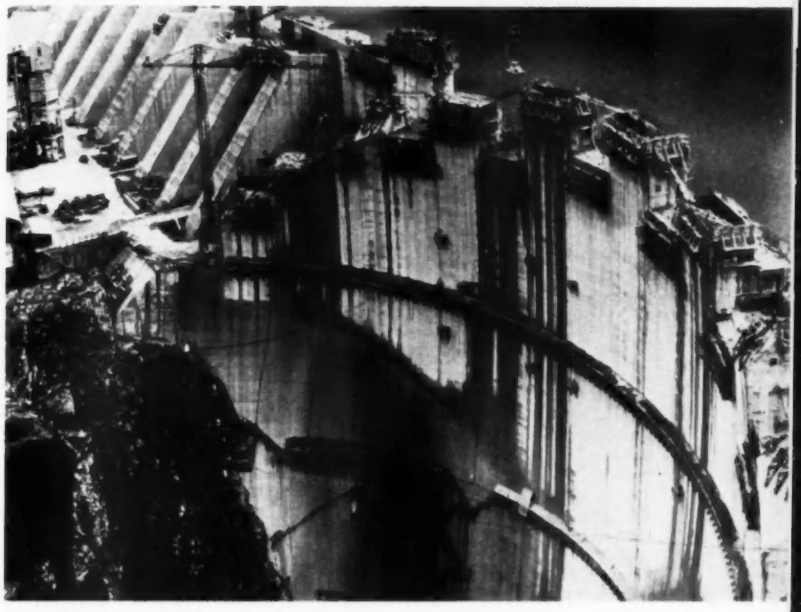
CONTINENTAL AFFAIRS

by Our Continental Editor

Roselend Hydro-Electric Scheme

No. I

The Roselend scheme is described as the " pièce maîtresse " *of the French hydro-electric programme. It utilises an extensive area of Alpine catchments, through a major reservoir at high altitude, and a single high-head power station which is the largest hydro-electric station in France. The scheme includes a dam of unique design combining an arch and buttresses, a pressure tunnel obviating a secondary power station close to the dam, and a penstock of the greatest capacity yet built. Advanced design has been instrumental in reducing the cost of the scheme to within the economic limits imposed by electricity tariffs.*



IN the general survey of French water power published last week, we discussed the critical importance of seasonal storage in the comprehensive development of the major Alpine river catchments, and in particular of the Isère. The Roselend scheme provides the second seasonal reservoir (the first is at Tignes) to be built on the scale of complete utilisation in the Isère basin. Thus the storage at Roselend reservoir gives the scheme an attractive peak load output in winter, when combined with its high head of 1200m. The scheme's installed capacity is 500MW which is nearly one-twentieth of the maximum peak demand of the French public supply system, and its annual output is a 1000 million kWh, i.e. one-thirty-fourth of French hydro-electric output, though the latter fraction is not a measure of the importance of the scheme due to its peak load capability. About half the scheme's full capacity can be transformed directly to 380kV for long distance transmission, and the power station will serve for frequency regulation of the grid.

The principal statistics for the scheme are listed in Table I. It is situated in Savoie, and its aqueducts tap the right bank catchment of the River Isère as shown on the map in last week's article (page 212). Its power station, which is called La Bathie, is nearly 5 km East of Albertville.

Apart from the lengthy paths of the aqueducts, the overall layout of the scheme is simple. The intake is a separate structure from the main dam, and leads to a long pressure tunnel which has four side-stream intakes along its length. One of these intakes is served by a tunnel leading from a subsidiary reservoir (St. Guérin) formed by an arch dam. Beyond the surge shaft there is a single penstock, partly on the surface, but buried for the lower part of its length, which leads to the underground power station, and thence to a tail race tunnel and canal debouching into the Isère. There is one tunnel aqueduct feeding the main diversion system into the main reservoir. This tunnel will discharge through a small remotely controlled power station known as Les Sauces, or alternatively to a subsidiary reservoir called Gittaz. This subsidiary reservoir will also be connected to the main reservoir by a short tunnel, and will be operated as a compensation basin to be emptied into the main reservoir when the latter is drawn down. Gittaz reservoir will also be formed by an arch dam, but neither Gittaz dam nor Les Sauces power station have yet been constructed.

The power station at La Bathie is an installation with six 83·5MW vertical-shaft turbo-alternator sets, each driven by a Pelton wheel. Because of its importance for peak loads, the power station has been designed so that its machines can be started and brought to their full power of 500MW in three-and-a-half minutes.

With the redistribution of flow resulting from the aqueducts of the scheme, there will be a loss of output from the middle Isère stations and from certain stations on the Doron de Beaufort. This latter is the catchment in which Roselend reservoir is situated, and the Doron de Beaufort power stations will now be served only from the northern group of streams controlled by La Girotte reservoir, flow from the southern group now going into Roselend reservoir and thence to La Bathie. The result is that while the output of the Roselend scheme is 1000GWh, the net gain in output is 700GWh ; nevertheless the 300GWh transferred to the new power station has increased peak load value.

Roselend Dam

Roselend dam is even more exceptional than any other feature of the scheme. It is about 20m less in height than Tignes dam, which is the highest in France, but it contains about a third more concrete (the principal data are listed in Table I) and is thus the largest concrete dam so far attempted in France. Although the size of the dam is outstanding, however, it is the novelty of its structure which immediately attracts attention. The sketch overleaf shows its structural concept more vividly than a plan or elevation would do, and how well adapted the structure is to the topography of the site. The deep gorge is closed by an arch, which has a maximum height of 492ft (lowest foundation to crest) and is distinguished by the sloping line of its crest, which is such that the abutments of the arch in the rock extend to only about two-thirds of the full height of the arch. The spur to the left of the arch is closed off by a buttress dam, and the buttresses continue across to close off the triangular spaces left on each side of the sloping crest of the arch. The stems of these buttresses abut directly on the arch.

Other shapes were investigated, but the one shown had a margin of economy over its alternatives which was sufficient to reduce the cost of the storage it provided to an acceptable figure. The success of this novel and economical structure was thus the key to the economy of the scheme as a whole. The dam was designed by Messrs. Coyne and Bellier. With the death of M. Coyne last autumn, Roselend dam may be regarded as a worthy crown to his lifetime of achievement in this field.

The idea of inclining the crest of an arch is a refinement introduced by M. Coyne in recent designs, notably at the Grandval multiple-arch dam (illustrated in last week's article) and at Roselend. The method of stress analysis he favoured at one time considered a "diving arch" element following the thrust line in the structure, and it is just such an element which forms the crest of the Roselend arch. He explained the idea in the following words :* " It was considered superfluous to build massive abutments right up to the crest for taking the thrust of the arch, since the thrust is only considered as being horizontal to satisfy the mind. At Roselend the arch itself, which is struck-off obliquely, transmits the sloping thrust exerted on the upper part direct to the foundations."

In the general case of an arch dam, it was considered there would be economy in omitting the top parts of the abutments, sloping the crest, and then enclosing the two triangular gaps with some subsidiary structure, such as two short lengths of gravity dam. In the special case of Roselend, there was clearly a far greater incentive to utilise this concept, for if an abutment were needed for the full height of the arch (on the left hand side in the sketch) a costly and complicated tower-like construction would have been called for. It is of interest that an artist's sketch for the proposed arch dam of the Glen Nevis hydro-electric scheme in Scotland shows such abutment towers holding the upper part of the main arch.

The loading imposed by constructing buttresses directly against the arch introduced no major problem. The sloping plane delimiting the arch

* From " Engineering News Record," September 11, 1958.

CONTINENTAL AFFAIRS *(Continued)*

is sensibly parallel to the downstream slope of the buttresses, i.e. in the same direction as the thrust transmitted from buttress to arch. The upper part of the arch (i.e. over the 200 metres of gorge where a direct foundation for the buttresses is impossible) can therefore be considered in this respect as a series of inclined, stable arches transmitting thrusts sensibly in their own plane and carrying them back to the abutments ; it was considered sufficient in this region to thicken the structure somewhat, so as to incline the resultant thrust sufficiently for stability.

Analysis of the Arch

As to the main arch itself, after preliminary calculations had indicated the success of the design in general terms, further refinements and a more detailed appreciation of its behaviour were sought, so a series of models were built comprising (*a*) a rubber model of 6/1000 scale ; (*b*) models of plaster of 1/400 scale.

A " diving arch " analysis of the shape corresponding to the rubber model† indicated maximum compressive stress of 75kg per square centimetre‡ at the intrados springing near the bottom, and a horizontal tension of 25kg per square centimetre at the intrados key near the bottom. Thermal stresses were not included in these figures. The rubber model itself indicated satisfactory thrust at the key for the full height, but 100kg per square centimetre maximum compression near the springing and excessive tension on the upper downstream face in the zone of the key. It was at this stage that work on the plaster models was undertaken ; doubt was expressed of the validity of transforming the rubber model results to the prototype because of the disparity between Poisson's ratio for rubber and for concrete (the same question was discussed in some detail in the papers on the analysis and testing of Dokan dam read before the Institution of Civil Engineers in 1956). These latter tests confirmed that the high value of Poisson's ratio for rubber had influenced the results, and indicated a corresponding maximum compression of 80kg per square centimetre and a corresponding tension of 17kg per square centimetre. The shape of the arch was thus considered acceptable, but further refinements were sought to improve it, and to eliminate the horizontal tension almost entirely.

Another, complementary, study influenced the final design at this stage. All these models had reproduced a dam with a crest level of 1573m a.s.l., giving 240 million cubic metres of storage. A study of the project as a whole indicated that it would be more economical and there would be various technical advantages in reducing the crest level of the dam to 1557m, thus reducing the storage to 187 million cubic metres, and providing the remaining 53,000,000 in two subsidiary reservoirs, namely 13,000,000 at St. Guérin and 40,000,000 at La Gittaz, following the general lines of the scheme as already described in the earlier part of this article. Final studies were therefore undertaken with plaster models at the new crest level to solve the remaining problems of detail needed to complete the design.

Some of the principal results obtained for the final design were : maximum compression 75kg per square centimetre near the abutments at the bottom of the gorge, and 60kg per square centimetre in the upper zone ; tension on the downstream key section practically gone ; maximum deflection at the crown of the key section (instead of at about the upper third in a classical arch) and equal to just over 16cm, assuming E=100,000kg per square centimetre for the concrete. Also differential displacements of several centimetres due to the deflection at the crown would be produced between neighbouring buttresses abutting on the arch.

Three complementary calculations completed the design analysis. They concerned temperature effects, displacements of the right bank abutment, and interaction with abutting buttresses. Temperature stresses were computed to be, under the worst conditions, equivalent to tensions of about 9kg per square centimetre at the upstream key and 20kg per square centimetre at the downstream springing, assuming E for concrete equal to 150,000kg per square centimetre for this calculation. Second, the unsymmetrical displacement of the abutments under load (the right bank one displaces more) induced a stress of only a few kilogrammes per square centimetre at the abutments, it was calculated, assuming $E_{rock} : E_{concrete}=3$. In both these calculations, the dam was considered divided into the ring elements defined in the geometric sketch, and linear stress/strain relationships assumed for each element. Finally, stresses in the buttresses resting on the arch were computed from the arch displacement, as they had not been exactly represented on the model ; a maximum tension of 5kg per square centimetre at about the 1500m level is introduced, with compression lower down, due to this interaction.

Buttress Design

The shape of the buttress dam was determined both from technical and architectural considerations, and from the fact of interaction with the arch at certain buttresses. This last fact, and the existence of an abrupt slope away of the foundation rock towards the upstream, were two factors favouring a vertical upstream face. The span between buttresses was fixed at 20m, and the diamond-headed shape adopted, with a plane downstream face to the buttress head, perpendicular to the axis of the buttress. Model tests relying on strain gauges and photo-elastic methods confirmed the value of this shape and the absence of horizontal tension on the upstream face. Horizontal drains were placed 2m from the upstream face to relieve uplift pressure, with reinforcement close to the face. The stems of the buttresses were made 5·5m wide at the 1550m level, increasing to 7·5m at 1500m, and remaining at 7·5m thick lower down.

A buttress element was analysed to ensure there was no vertical tension, that tan ϕ (ϕ=angle of resultant thrust with the vertical) at the 1500m level did not exceed 0·75, not taking into account uplift, and to ascertain the principal stress trajectories. Maximum shear at the toe was computed to be 11·9kg per square centimetre (i.e. half the compressive stress acting parallel to the downstream face). Earthquake stresses were also analysed, and the deformation, due to hydrostatic thrust, of the spur of rock on which the dam stands was computed.

Construction of the Dam

The art of constructing large dams being at a mature stage in France, it would be expected that all aspects of construction would receive, on a major scheme such as Roselend, the same skill and attention to detail that characterised the structural design. That in fact proved to be the case, and our only excuse for referring so briefly to these other aspects is that they are more conventional and are largely common to the construction large dams. One other special problem is, however, described a little more fully, namely the specification for the concrete of the dam.

The ancillary works comprise a scour culvert but no spillway ; the intake is separate from the dam, though the access tunnels to the sluice valves in the intake tunnel pass under it.

Watertightness of the buttress dam depends on upstream seals between buttresses which are illustrated in the diagrams ; behind these seals there is a system of drains and below them there is a concrete cut-off ; note particularly the special joint between buttresses abutting on the arch.

The main arch was constructed in blocks each structurally stable at all times, following methods considered as classical by French engineers. There is a double sealing system at the joints of the arch. A grouted curtain of rock extends to a maximum depth of 130m. A rather elaborate instrumentation is built into the dam, including vibrating-wire strain gauges.

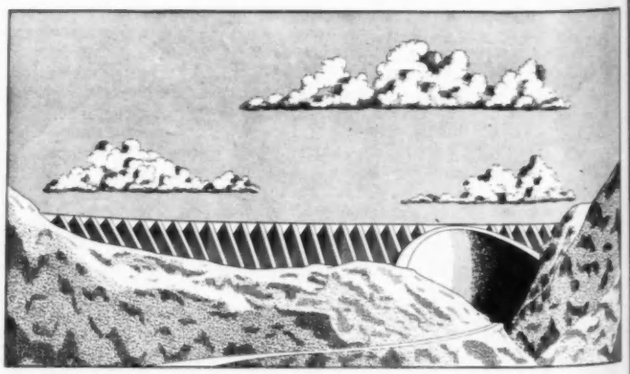
Aggregate was won from a quarry nearby, the quarry plant having a capacity of 600 tonnes per hour. Three concrete stations were built; one of 90 cubic metres per hour capacity (reckoning twenty mixes per hour) in the gorge for concreting the lower arch, had three mixers installed in it, each giving 1500 litres of concrete, in place, per mix. A second station of the same type and capacity was built on the spur, and the third one, which was beside it, though also similar, had only one or two mixers installed at different stages of the work ; the two upper stations served the buttresses and the upper part of the arch. Concrete was placed by two cableways, each of 10 tonnes capacity and with adjustable masts, and by an installation of tower cranes.

A daily rate of concreting of about 2200 cubic metres was maintained with a labour force of 850.

Excavation was completed by the end of the 1957 season, and the first concrete was placed in August of that year. The main concreting took place in the last three summers and impounding started last summer ; the dam will be finally completed this summer.

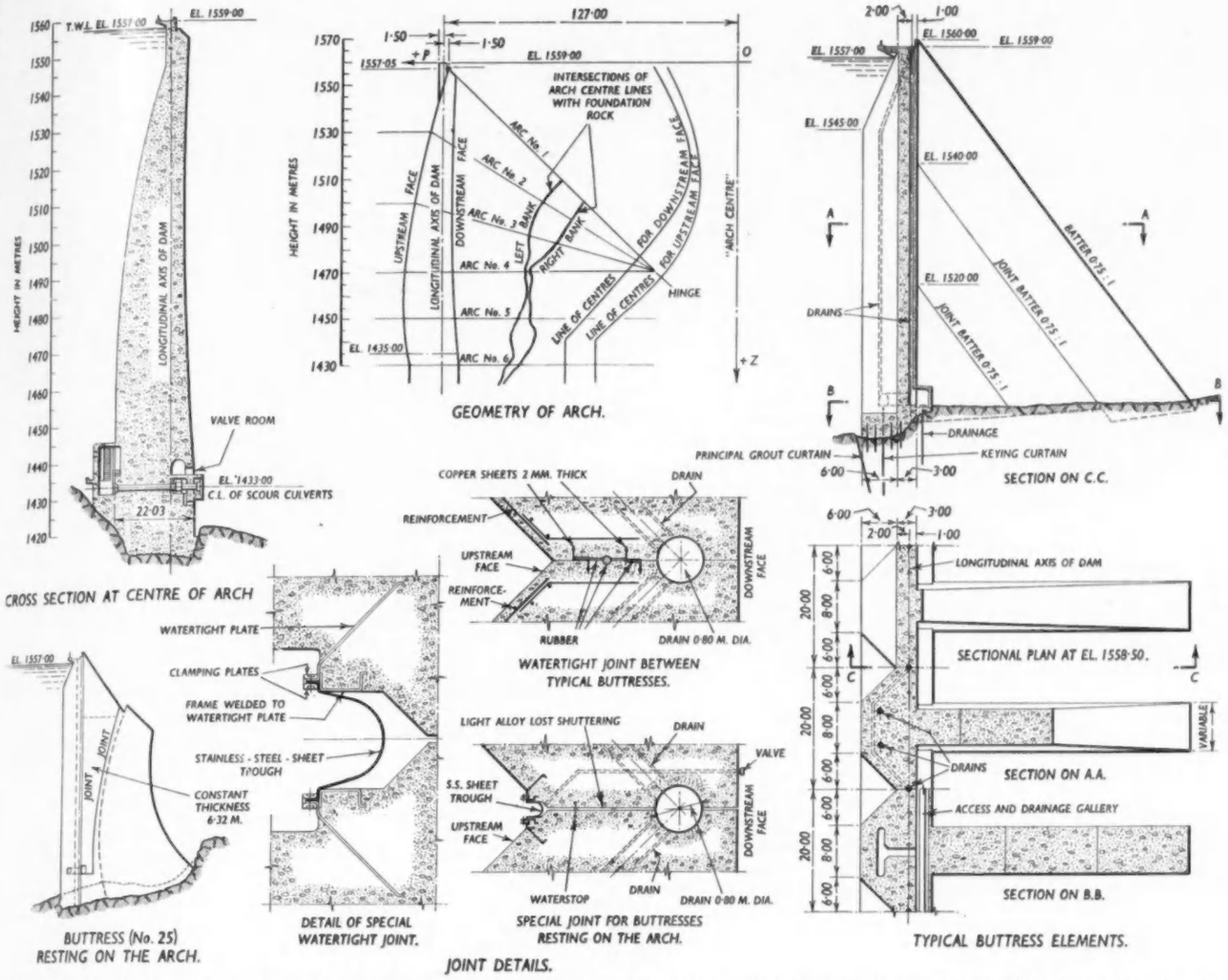
Concrete for the Dam

Special studies were undertaken to " design " the concrete for Roselend dam. At the high altitudes of the seasonal Alpine reservoirs, an important property of the concrete is its resistance to frost, for sunny days in winter produce severe cyclic conditions of freezing and thawing. In the description of Tignes dam given in our earlier series on the Isère power schemes, that problem was discussed. The same experience was valid in this case, but further work has since been done on this problem, and it is considered that the concrete of Roselend dam can be considered truly permanent giving a long life at the duty required by this somewhat highly stressed, slender structure. Tests on specimens of concrete were carried out to ensure that a minimum standard of performance in relation to frost resistance would be achieved, namely, with-



Artist's impression of Roselend dam from downstream. The sloping line of the crest of the arch and the buttresses abutting directly on the arch are clearly shown. The two photographs reproduced at the heading and on page 246 show the dam as it was during the 1960 constructional season.

† We are indebted to the journal " Travaux " of August, 1958, for some of the data given here on the design of the dam.
‡1 kg per square centimetre=14·22 lb per square inch.


CROSS SECTION AT CENTRE OF ARCH
GEOMETRY OF ARCH.
SECTION ON C.C.
BUTTRESS (No. 25) RESTING ON THE ARCH.
DETAIL OF SPECIAL WATERTIGHT JOINT.
WATERTIGHT JOINT BETWEEN TYPICAL BUTTRESSES.
SPECIAL JOINT FOR BUTTRESSES RESTING ON THE ARCH.
SECTIONAL PLAN AT EL. 1558·50.
SECTION ON A.A.
SECTION ON B.B.
TYPICAL BUTTRESS ELEMENTS.
JOINT DETAILS.

Note on Geometric Sketch.—Horizontal sections of the upstream and downstream faces are curves known as "Limaçons de Pascal" (Pascal's Spirals) defined in polar co-ordinates from the "Arch centre" marked on the sketch. Pascal's spiral is the locus of the feet of perpendiculars dropped from a fixed point to the tangents of a circle. Taking this point as the origin, for a circle radius R with its centre on the x-axis at $x=a$, the equation of the curve is $(x^2+y^2-ax)^2-R^2(x^2+y^2)=0$.

Note on the Special Joint.—Two buttresses on each side of the centre of the arch abut directly on the arch. For the six joints of these buttresses, rather large displacements have to be accommodated, and movement in two directions allowed. The essential element of the joint is thus a trough of stainless steel sheet, installed so that it can be inspected and replaced if necessary.

Typical details of the arch and buttresses of Roselend dam

standing 250 freezing/thawing cycles with twelve hour periods at −30 deg. Cent. and +18 deg. Cent. in each cycle.

One interesting aspect of this work has been an extensive study of air-entraining and plasticising additives carried out at the laboratories of the Région d'Equipement Hydraulique Alpes 11 at Albertville. In reporting this work, M. Orth§ has published a systematic comparison of various admixtures at various concentrations on : setting speed ; air entraining ; plastification ; resistance to frost ; and strength, given that frost resistance was achieved. He points out that the laboratory's method of research offers the possibility of finding admixtures of considerable importance in improving the permanence of concrete (i.e. its frost resistance and strength) perhaps giving a life five or six times as long as present-day practice ensures.

More generally, the concrete was governed by the following criteria : compressive strength at one year, average 350kg per square centimetre, minimum 300kg per square centimetre ; as high a tensile strength as possible ; moderate modulus of elasticity ; a structure such that small permanent displacements would result after the first filling of the reservoir, and elastic behaviour would be obtained thereafter ; as little shrinkage as possible ; high density ; and adequate impermeability. The result was a concrete made as below, described according to the "brief description" recommended by the international sub-committee on concrete of the Congress on Large Dams :

(*a*) Cement content 250kg per cubic metre (giving a ninety-day strength from 60cm test cubes of 360kg per square centimetre).

(*b*) Effective water/cement ratio, about 0·5.

(*c*) Type of cement. Portland low-heat cement with finely-ground granulated slag ; slag content not more than 30 per cent ; manufacturers Sté Ardelor. Maximum heat of hydration 65 cals/gram at seven days. This cement, known commercially as "Roselend 303" follows the French standard P15-303 (see "Travaux," August, 1958, for full specification).

(*d*) Petrology of aggregate : gneiss from a quarry (Meraillet) close to the dam. Mean density 2·2. Gradings in millimetres : 160/60, 60/18, 18/6·4, 6·4/2·4, 2·4/1, and 1/0·1. Quarry-run sand, separation of the sand fractions 2·4/1 and 1/·01 and elimination of sand grains <0·1mm by "Rheax" hydraulic separators.

(*e*) Method of compaction : by manually and mechanically operated immersion vibrators (frequency=10 to 12,000 c/s).

The manually-operated vibrators were of 95mm diameter, and were driven by a 3kW electric motor ; the heavier, mechanically-operated ones were of 120mm diameter, and were driven by a 6kW motor.

(*f*) Air entraining agent : "Cerygel," 50 to 75 grams per cubic metre.

(*g*) Estimated air content of finished concrete : tests have shown that if a percentage of 3 to 3·5 of air content in the finished concrete is desired, the percentage of air in the concrete leaving the mixers must be about 4 to 4·5.

(To be continued)

§"Selecting and Checking of Plasticising and Air-entraining Admixtures (Albertville Laboratory Method)." Paper R131, Sixth Congress on Large Dams, New York, 1958. See also the Seventh Congress (Rome, July, 1961) for several papers on specific aspects of the Roselend Scheme, and also on the Serre Ponçon scheme described last week.

Verein Deutscher Ingenieure

The Annual Report for the year 1960 of the Verein Deutscher Ingenieure, which has just been published, again brings a summary of the many-sided activities of this the largest technical-scientific association of the German Federal Republic. It is headed by the Director's report concerning the education of engineers and the proposed embodiment in legislation of the status of engineer. The thirty-eight district associations and their many technical subgroups have held a total of over 2318 lectures, discussion meetings, visits and courses. The Association's paper "VDI-Nachrichten" is now being published weekly instead of fortnightly: with its edition of 80,000 copies it is by far the largest technical newspaper in Europe. Many technical courses were again organised by the VDI Educational Section, as well as Travelling Teaching Exhibitions which were held in many towns.

Conference on New Energy Sources

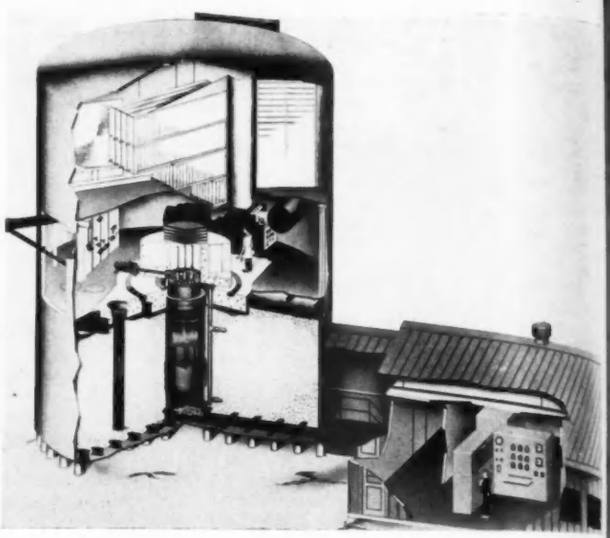
During the period August 21 to 31, the United Nations Organisation is arranging a conference in Rome on "New Sources of Energy." The conference is mainly aimed at the needs of countries in process of industrial development where muscle power, of animals or even man, still is the predominant factor in the economy: such power, as it depends on food, is approximately twenty times as expensive as present-day nuclear energy. The discussions will be concerned with solar devices (cookers and furnaces with mirrors, solar pools, solar batteries), semiconductor thermocouples, wind power, fuel cells, and geothermal heat.

THE AMERICAN SCENE

By Our American Editor

Nuclear Reactor Accident in Idaho

A serious accident took place at the SL-1 (Stationary Low Power No. 1) reactor at the National Reactor Testing Station of the U.S. Atomic Energy Commission near Idaho Falls, Idaho, on January 3, and was initially reported in our issue of March 3. Further details have now been obtained pertaining to the circumstances surrounding the explosion within the reactor vessel. Before the accident, there appears to have been a continuing deterioration of the burnable poison strips within the core and a worsening of the scram performance of the control rod system, neither of which circumstances necessarily was directly related to the incident. The evidence strongly indicates a nuclear accident of 50 megawatt-seconds, or more, which could credibly have been induced by rapid and extensive motion of the central control rod. There is no evidence, however, to show that the actions of the operators on duty were in any way different from those prescribed and which had been carried out without incident many times before.



THE SL-1 reactor at the National Reactor Testing Station (N.R.T.S.) in Idaho is a direct-cycle, boiling water reactor designed to operate at 3MW (thermal) gross capacity. The electric power and process heat are dumped to the atmosphere through load banks and heat exchangers respectively. The reactor is fuelled with enriched uranium plates clad in aluminium, moderated and cooled with light water in natural circulation. The reactor vessel is 4·5ft in diameter and 14·5ft high. It is surrounded by gravel on the sides and is supported on a concrete pad resting on lava. The following equipment and components are situated within the large silo-like structure : the reactor vessel, the turbo-generator, the heat exchanger and other water-handling components, the air-cooled condenser, and fans and miscellaneous control equipment. The reactor control room is situated in the adjacent support-facilities building. The reactor building was not designed as a leak-tight containment structure.

At 3MW (thermal) power level, a saturated steam flow of 9000 lb per hour was generated in the pressure vessel at 300 lb per square inch gauge and 420 deg. Fah. About 85 per cent of the steam was used to generate electricity. Fifteen per cent of the steam by-passed the turbine into a heat exchanger, which simulated a space-heat load. The air-cooled condenser was used to reduce the requirement for water during operation.

A reference reactor core array of forty fuel assemblies was designed. Channels were provided for a total of nine control rods : five 14¼in span cross rods (Fig. 2) and four " T "-shaped rods. In each rod, the cadmium absorbing section was 34in long, and, when the rods were positioned at indicated zero withdrawal, the cadmium overlapped the bottom and top of the active core by several inches. It was anticipated that the " T "-shaped rods would not be used in the reference 3MW core of forty fuel assemblies but that it might be desirable to use them in a later full-size core of fifty-nine fuel assemblies. Originally, it had been intended to disperse a burnable poison, essentially in the form of boron, fully enriched in boron-10, in the fuel matrix. Because of developmental problems, not necessarily related to the boron in the fuel matrix, it was finally decided to expedite the procurement of the fuel assemblies by the omission of boron from the fuel matrix. The neutron absorber was introduced in the form of thin, flat plates, welded to one or both side plates of the fuel assemblies, as had been done in the " Borax III " experiment. The full-length burnable poison strips, fabricated of X-8001 aluminium alloy and highly enriched boron, were positioned in the core so as not to be adjacent to the control rod channels. Additional half-length strips were also attached to the bottom half of the opposite side plate of the sixteen fuel assemblies in the centre of the core.

Project Administration

The SL-1 reactor, originally designated the Argonne Low Power Reactor (A.L.P.R.), was designed as a prototype of a low-power, boiling-water reactor plant to be used in geographically remote locations. A request for such a plant to be built by the A.E.C. was made by the U.S. Department of Defence in a letter dated September 27, 1955. The development and final design of the plant were assigned by the Division of Reactor Development, A.E.C., to the Argonne National Laboratory, to achieve an early operational version of this type of plant. The design and proposed operation of the reactor were reviewed in February, 1958, by the Hazards Evaluation Branch of the A.E.C. and also by the Advisory Committee on Reactor Safeguards. Approval was given by both of these groups for the operation of the plant, as designed, at power levels up to 3MW (thermal). The staff report stated " when higher power-level operation is contemplated, a report of additional hazards and consequences of operation at this new power level should be submitted together with a report of the operating experience at the 3MW level."

The part played by the Argonne National Laboratory, under contract with the Division of Reactor Development, included the design, test and initial operation of the reactor plant. This work was carried out between 1955 and 1959. Initial critical operation took place on August 11, 1958, and test operations culminated in a 500-hour run which ended in December, 1958. Argonne's official part ended on February 5, 1959, when Combustion Engineering, Incorporated, assumed the contractual responsibility for the plant. While Argonne has had no official responsibility since this time, its employees have, on several occasions, visited the reactor site to observe fuel inspection, or have otherwise reviewed plant performance.

Operating History

The SL-1 reactor achieved criticality on August 11, 1958, with ten fuel elements containing a total of 3·5 kg of U-235. There followed a series of critical experiments performed in the reactor, with and without poison strips, to determine the optimum fuel and poison loading to achieve the design objectives. As a result of these critical experiments, a core was chosen with forty fuel elements, forty full-length and sixteen half-length boron strips and five control rods. The differential and integral worth of the five control rods were obtained as a function of rod insertion into the core. Flux plots were made of the hot, zero power cores by the use of irradiated gold and copper wires.

On October 24, 1958, the SL-1 achieved its full power rating of electricity and space heat. During October 29 to 30, 1958, a forty-hour xenon run was made. The SL-1 was then shut down and eight hours later the reactor was brought to full power, overriding peak xenon. There followed a 500-hour run at full power. The 500-hour run continued until December 11, 1958. The reactor was operated at a power level of 3MW (thermal) up to November, 1960. The plant remained shut down until March 6, 1959, for maintenance and inspection and for the preparation of operating procedures and manuals. The SL-1 reactor was turned over to Combustion Engineering, Incorporated, for operation in February, 1959.

A 1000-hour sustained power run was concluded in July, 1959, and the plant then remained shut down for about a month for maintenance, modification and inspection. Important shut-downs occurred in August, 1959, January, 1960, November, 1960, and December, 1960, to permit maintenance and inspection. Fuel elements were first removed from the core during September, 1959 for inspection. Subsequent inspections took place in October, 1959, August, 1960, and November, 1960. Initial discovery of the bowing of the boron strips, in the 3in sections between tack welds, was made in 1959. During the August, 1960, inspection it was observed that large amounts of the boron strips were missing from some fuel elements and the fuel elements in the centre of the core were extremely difficult to remove by hand. Removal caused plates to fall off and flaking of material. A considerable number of flakes were collected from the bottom of the vessel. As a result of these circum-

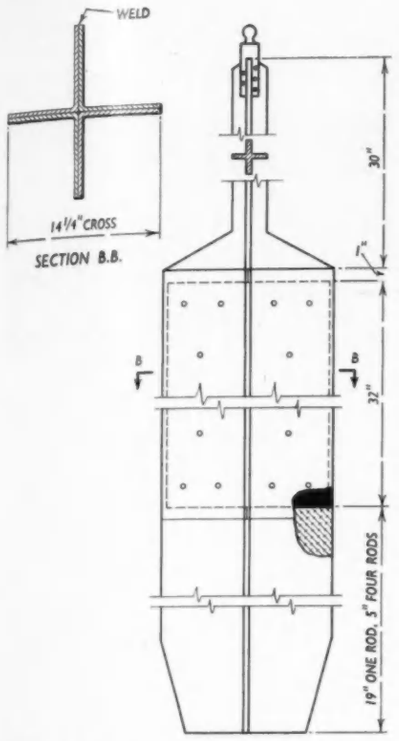


Fig. 2—Design of cross-type control rod of SL-1 reactor

stances, it was felt that further removal of fuel elements might cause further loss of boron, so that no further inspections were conducted. It was noted during the second periodic inspection in August, 1959 that the central fuel elements were difficult to remove.

The design goal for the SL-1 reactor core was operation at design power level, allowing for normal outage, for a period of three years. The boron strips were incorporated in the core design to serve as a burnable poison, the depletion of which would compensate for the burning of fuel. Ideally, such an arrangement would lead to a constant reactivity value for the core at operating conditions, which would be manifested by a nearly constant position of the banked control rods. The calculated reactivity behaviour, in terms of banked rod position/core exposure, is given in the graph (Fig. 3). Also plotted are the observed rod positions as a function of exposure. By May, 1960 (500MWD) it appeared that the core was gaining reactivity faster than predicted. In August, 1960, routine inspection of selected fuel elements revealed the extensive loss of boron. The large rate of gain of reactivity was ascribed to this boron loss. Of greater safety significance, the greater rate of reactivity gain, and, in fact, the larger amount of reactivity gain, reduced the capability of the control rods to render the core sub-critical. The

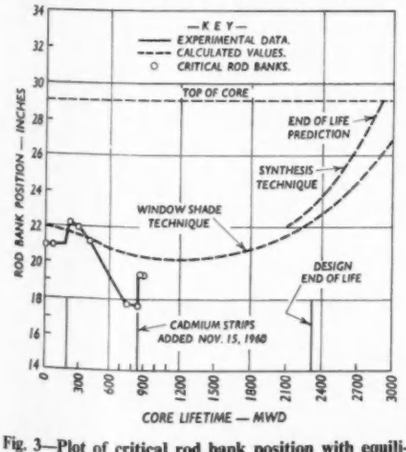


Fig. 3—Plot of critical rod bank position with equilibrium concentration at 2·56MW

graph (Fig. 4) indicates, as a function of core exposure, the banked rod position for different operating conditions. From these data, and from estimates of the worth of the control rods, estimates of the shut-down margin were made. Because of the reduced shut-down margin, resulting from the boron loss, strips of cadmium were inserted in two of the "T"-rod control shrouds on November 11, 1960. The banked rod position, with the reactor cold, was determined at an exposure of 711MWD, but not thereafter. The last part of the curve for the cold condition is an assumption of cold reactivity behaviour, based on the observed behaviour of the banked rods during equilibrium operation at 2·56MW (thermal). Thus, the effect of the cadmium at 2·56MW (thermal) was observed to be approximately 1 per cent in reactivity, and this was assumed to be the case also with the reactor cold.

The operator's estimate of the reactivity worth of the boron, at the beginning of core life, was 11 per cent. A rough observation of a 2 per cent gain in reactivity over that predicted, which was attributed to the loss of boron, led to the estimate that 18 per cent of the boron originally present was missing from the core. Although numerical values for core reactivity, rod worth and shut-down margin are all subject to some uncertainty, the available information indicates the following :

(1) The initial shut-down margin for the cold reactor was probably somewhat less than intended—approximately 3·5 per cent Δk actual margin versus an estimated 4 to 6 per cent design margin. The actual margin was considered adequate.

(2) The reactor could have been made critical by withdrawal of the central control rod only, at any time since the start-up of the reactor.

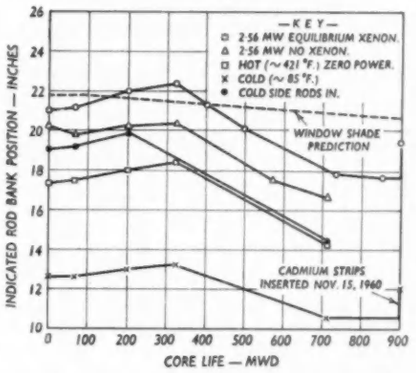

—KEY—
2·56 MW EQUILIBRIUM XENON.
2·56 MW NO XENON.
HOT (~421 °F.) ZERO POWER.
COLD (~ 85 °F.)
COLD SIDE RODS IN.
WINDOW SHADE PREDICTION
CADMIUM STRIPS INSERTED NOV. 15, 1960
INDICATED ROD BANK POSITION — INCHES
CORE LIFE — MWD

Fig. 4—Plot of SL-1 rod bank position *v.* core life

(3) At the time of shut-down on December 23, 1959, the shut-down margin for the cold reactor was probably 2 to 3 per cent, assuming the rod worth was essentially unchanged from earlier measurements and calculations. With this assumption, and a similar one regarding the central control rod, criticality could be produced by withdrawal of this rod approximately 17in from the reference zero position.

Control Rod Drive

From early operations onwards, intermittent and increasing difficulty was encountered in the free movement of the control rods. At least over the first year of operations, and possibly in large measure thereafter, the difficulty arose from the abnormal performance of the seals through which the drive shafts penetrated the rack-and-pinion-gear housings on top of the reactor. The rate of flow of seal water affected the performance of the rod drives, as did the presence of foreign matter. Increased filtration apparently reduced the problems associated with foreign matter. A study was in progress to seek an understanding of the variation of the scram performance of the rods with seal water flow. This variation was not considered a serious problem, in that performance specifications were met, provided the seal water flow was at the design value. It was also stated that movements imposed in scram tests prior to reactor start-up and frequent exercise of the rods seemed to improve rod performance, possibly by tending to clear out particles of dirt or dust in seals or bearings.

In more recent months, testimony and operating records indicated an increased frequency of malfunctioning of the control rod drives. On the one hand it was postulated by several witnesses that the bowing of the boron strips attached to the fuel elements exerted sufficient lateral force to result in reduction of the clearance within the control-rod shrouds, restricting the free motion of the blades. On the other hand, several witnesses felt there was no evidence for such closing of the shrouds, but that there might be some accumulation of crud on the shroud and blade surfaces ; and that exercising the drives tended to prevent sticking of the rods in the shrouds. It was also indicated that the higher power operation, which took place only after November, 1960, and the addition of the cadmium strips required further withdrawal of the control rods than had been previously required. Consequently, the drives were being used in a new region of the mechanical structure, where closer tolerances, or other differences, caused increased difficulties with rod motion.

The only known interferences within a shroud were as follows : (1) A crimp or similar bend was observed in the top edge of the No. 1 shroud. A special stainless steel wedge-shaped tool was designed and used to straighten out this defect. (2) A dummy control blade, made of aluminium, was fabricated for insertion and irradiation in the No. 4 shroud. On initial insertion, the blade could not be fully inserted. The wedge-shaped tool was used on this shroud also, but since it could not be inserted within the shroud, the actual remedy for insertion of the blade was to cut a portion off the bottom of the blade.

Nuclear Accident

After having been in operation for slightly more than two years, the SL-1 was shut down on December 23, 1960. It was planned that maintenance on certain components of the whole system would be performed during the succeeding twelve days and the reactor would again be brought to power on January 4, 1961. While maintenance work on several auxiliary systems of the plant was completed during this period, the only work planned for the reactor core was the insertion of forty-four cobalt flux measuring assemblies into coolant channels between plates of the fuel elements throughout the core. Access to the core, to install these assemblies, was through nozzles in the head of the reactor vessel, which required removal of the control rod drive assemblies. This portion of the work was begun during the early morning hours of January 3, 1961. When the day crew arrived at the SL-1 on January 3, dismantling had been completed. Installation of the flux measuring assemblies was accomplished during the day shift.

The crew of the next shift (4 p.m. to midnight, January 3) consisted of three military personnel : the shift supervisor (a qualified chief operator), his operator-mechanic assistant (a qualified operator) and a trainee. This crew and the following one were assigned the task of reassembling the control rod drives and preparing the reactor for startup. The first indication of trouble at the SL-1 reactor was an automatic alarm received at 9.01 p.m. on January 3, 1961. The alarm was immediately broadcast, and, at the same time, the personnel radiation monitor at the Gas Cooled Reactor Experiment gate house, about 1 mile distant, alarmed and remained erratic for several minutes. Upon the receipt of the alarm, which could have resulted from excessive temperature, high radiation, by being stuck by a missile, or a pressure surge in the region above the reactor floor, the Central Facilities A.E.C. Fire Department and the A.E.C. Security Forces responded. A health physicist from the Materials Testing Reactor was called at this time.

Upon entering the SL-1 fenced area, the fire department personnel were unable to arouse the SL-1 crew. Access to the reactor support building was gained through the use of the security patrolman's keys. The assistant fire department chief entered the reactor support building and immediately detected radiation levels up to 25 roentgens per hour. He could observe none of the SL-1 crew in the reactor support building. The health physicist from the Materials Testing

THE AMERICAN SCENE *(Continued)*

Reactor arrived and entered the reactor support building. He observed increasing radiation levels as he proceeded towards the reactor building ; he detected levels of 200 roentgens per hour at the stairway to the reactor.

The decision to enter into the reactor building to look for the operating personnel was made after the arrival of the plant health physicist. He found two of the crew on the floor near the reactor in a radiation field of approximately 1000 roentgens per hour. One of the two men was still living ; the other dead. The removal of the living man was accomplished by approximately 11 p.m. Shortly thereafter, he was pronounced dead by one of the A.E.C. physicians who responded to the emergency call. Subsequent entries were made over the next several days to remove the two remaining bodies and to recover certain equipment and records. Of over 100 people engaged in recovery operations during the first twenty-four hours after the incident and of the several hundred so engaged in the following week, twenty-two persons received radiation exposures in the range of 3 to 27 roentgens total body exposure. Precautionary medical check-ups did not disclose any clinical symptoms.

Injury to Personnel

The results of the post mortem examinations of the three deceased persons show that two of them died instantly as a direct or indirect result of blast damage and that the third man may have lived for about two hours after the incident. A fatal wound in the head of this third man precluded any possibility of survival. There was evidence of flash burns to limited areas of the bodies. Personnel exposures during the initial recovery operations are listed above. Since the removal of the third body, exposures to personnel engaged in the recovery operations have been limited to values less than normally allowed to radiation workers.

Physical Damage

There appears to have been only minor physical damage to the reactor building (Figs. 5 and 8). A buckling of the reactor room ceiling directly above the reactor has been observed. Two of the shield plugs were driven upward out of the nozzles in the head of the reactor vessel and penetrated and stuck in the reactor room ceiling. One of these plugs was removed during subsequent operations. A peeling back of a portion of this ceiling indicates the possibility that some additional parts of the reactor system, such as a shield plug, may have been projected into the fan room area.

No conclusive evidence is yet available as to whether or not the reactor vessel itself has been damaged. Preliminary estimates have been made that the explosion may have caused an internal pressure as great as 500 lb per square inch, from observed damage above the reactor vessel and from calculations of energy needed to propel certain components to observed locations. A portion of the sheet metal, covering some shield material on top of the reactor head, was bent upward, allowing dispersal of some of the gravel, steel punchings and pelletised boron shielding material.

Photographs taken by movie and closed-circuit television cameras have shown extensive damage to the core itself. The central control rod, No. 9, and a portion of its shroud appear to have been ejected completely from the core and are lodged below the central nozzle. Control rods Nos. 1, 3 and 7 appear to be within the core, though they may be displaced laterally and vertically to some extent. The shrouds of these control rods have been greatly distorted, and the top of the core is covered with debris from core components such as hold-down plates and end boxes from individual fuel element assemblies. The core has been expanded, from internal pressure, to the point that it is in contact with the thermal shield near the wall of the reactor vessel at many points on its circumference, removing the 6in to 9in clearance in the original core configuration. Two racks, which belong to control rods Nos. 1 and 7, are protruding from their respective nozzles ; the threads on the ends of both appear to be damaged. The rack associated with the No. 3 rod has been broken off near the upper surface of the No. 3 nozzles.

The bell housing over the No. 5 rod extension had not been removed during the shutdown work and is still in place. As a result of this, and because the position of rod No. 9 and its shroud have obscured vision, it is not possible to ascertain the position of this control rod. The plate over the No. 8 nozzle, through which the instrumentation leads from the core passed, was blown from the nozzle, stripping the threads from each of the studs. The present location of the No. 8 plate is now known. Of the five shield plugs, only three have been observed ; two in the ceiling of the reactor room and one lying on the top of the reactor head.

Thermocouple measurements and water-detecting probe measurements in the core have been made. Despite conflicting previous interpretations, it is now generally accepted that the level of the water in the reactor vessel, if indeed there is any water present, is at least 24in below the bottom of the active fuel. Since the first observations were made more than a month after the incident, it is possible that what water was present just after the incident had evaporated before observation. Although there is no evidence to support it, and activity levels below the reactor vessel would seem to indicate otherwise, it remains a possibility that the reactor vessel is cracked.

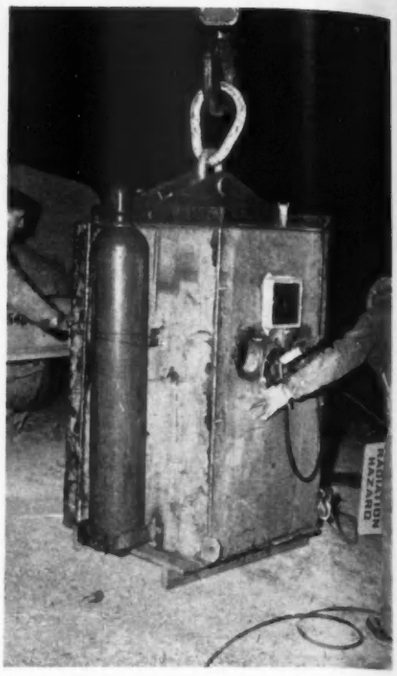


Fig. 6—Lead shielding box used to protect a welder who severed steel beams obstructing the reactor room entrance

Nature of the Incident

In the absence of any direct evidence which would identify the initiating event resulting in the explosion within the SL-1 reactor vessel, the Commission cannot state what actually did initiate the incident. There appear to be several conceivable mechanisms, or sequences of events, that could have resulted in the observed effects. The relative credibility of these mechanisms is extremely difficult to establish without further information. That an explosion took place is quite clear from the observed physical damage within and without the reactor vessel. Indications that a nuclear excursion took place were provided by the following : 1. Identification of the fission product yttrium-91 isotope, in a metallic sample shaken out of the clothes of one of the deceased. 2. Identification of activated copper-64 in a cigarette lighter screw, belonging to one of the deceased. 3. Identification of activated copper in a watch band buckle, belonging to one of the deceased. 4. Identification of activated gold in a finger ring worn by one of the deceased. 5. Identification of activated cobalt-58 in a gasket from the top of the reactor. 6. Identification of activated chromium-51 in a gasket from the top of the reactor. 7. Identification of gross fission products in air samples taken one and two days after the incident. 8. Response of monitoring instruments at nearby sites to the passage of a radioactive cloud. 9. Observations of radioactive iodine contamination of sage brush. The observed blast effects on equipment, components and personnel are not inconsistent with the conclusion that a nuclear excursion took place. Thus, the energy release required to produce the pressures needed to cause the observed effects is comparable to that observed in the destructive " Borax " experiment of the A.E.C. on the one hand, and credible mechanisms and initial conditions can be postulated, on the other hand, that would lead to such an excursion.

There have been no chemical, metallurgical or

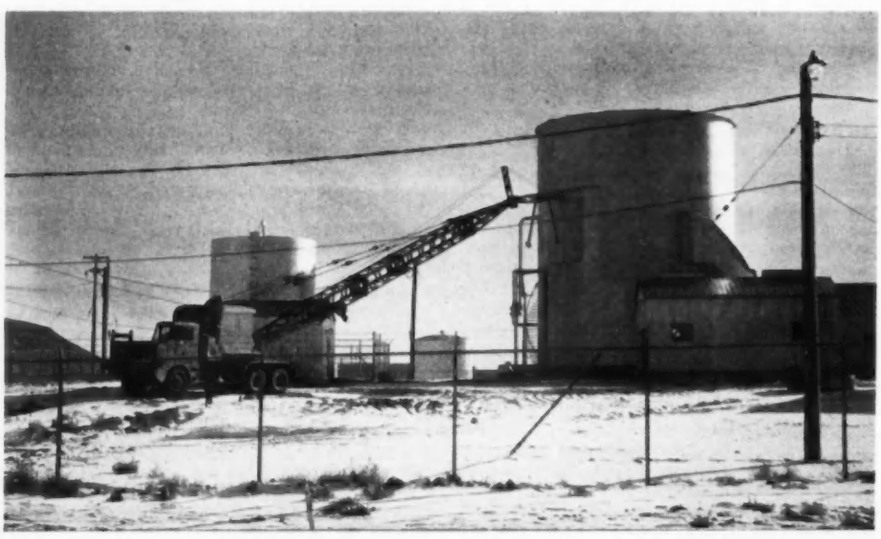


Fig. 5—Use of large mobile crane in breaching the service doorway of the reactor building after the accident

physical analyses of any materials or components, the results of which would support the hypothesis of an initial chemical reaction which then induced a nuclear reaction by rearrangement of core components. In this regard, metallurgical examinations made after the incident probably would not establish conclusively whether a metal-water reaction initiated or resulted from a nuclear excursion.

Energy Release

One estimate of the energy release is based on the analysis of a metallic sample taken from the clothing of one of the deceased. This sample was analysed for uranium isotopic composition, mass, and specific yttrium activity. This analysis, related by assumption to the total uranium present in the core, led to a rough estimate of the total fissions during the excursion of $1 \cdot 5 \times 10^{18}$—equivalent to 50 megawatt-seconds. It is believed that an an energy release significantly less than this would not have produced the observed blast effects, and that an energy release greater by a factor of 3 or 4 would have produced much more drastic blast effects. Another estimate of the total energy release, based on analogy with " Spert " experience, as well as observed atmospheric radio-activity, was a release as great as 500 megawatt-seconds, indicating that there may have been more than one burst, or that there was additional lower-power operation.

A number of estimates of integrated neutron flux have been made from the determinations of induced radioactivity in various samples. The extrapolation to the number of fissions in a nuclear excursion is extremely uncertain, however, because the energy release is not large compared to the cumulative exposure of the core, because of the unknown effects of shielding, and because of the unknown effect of delayed-neutron emitters released from the reactor vessel into the reactor room.

Activity Release

Aerial surveys conducted on several different occasions since the incident, at an altitude of 500ft and above, have not indicated any activity levels, at the ground, greater than twice background levels. On the basis of meteorological information and the observation of smoke plumes under similar conditions, together with air and ground samples, it appears that a narrow plume of gaseous fission products travelled S.S.W. from the reactor building. Low-level off-site activity of sagebrush, due to iodine-131, was observed after the incident. Subsequent sampling in the immediate vicinity of the SL-1 site indicated that low levels of gaseous iodine were released for a short period of time from the reactor or that iodine released at the time of the incident was undergoing translocation. As of April, 1961, the measured iodine-131 levels were essentially at background level ; close to the reactor building, soil samples did indicate a low contamination by strontium-90 for a period after the incident.

Fig. 8—Photograph taken on January 7, 1961, showing the general damage in the reactor room, with steel punchings and gravel from the reactor shield in the foreground

Intermittent radiation surveys in the vicinity of the SL-1 plant indicate that the gamma radiation has not decreased an appreciable amount During the first week in February the dose rates varied from the order of 10 r per hour, measured at the base of the reactor building, below the cargo door, to the order of 100 mr per hour, measured at a distance of approximately 300ft from the reactor building.

Possible Mechanisms for the Accident

From a consideration of the factors which may have caused this accident, it is possible to conceive of several different items or combination of items which may have constituted the immediate initiating event. The accident could have occurred with no errors being committed on the part of the crew, though certain errors on the part of the operators also can be visualised as possible initiating events. It is known that the tasks assigned to the operators (reassembly of control rod drives) involved the lifting of the control blades. Testimony now indicates that the chief operator and the operator had performed this same task at least four times before the occasion in question and that they had received specific training for this operation. Their training procedure included the explicit instruction that during dismantling, the control rod was not to be raised more than 4in. The reason for this limit was not given in the procedure. From the positions of the men after the incident and the injuries they suffered, one cannot rule out the possibility that one, or possibly two, of them were engaged in lifting the central rod at the time of the explosion. At present, however, there is no direct evidence on this point.

In the light of measurements made before the reactor shutdown on December 23, 1960, it is estimated that it would have been necessary to raise the central control rod a minimum of 16in at that time to produce criticality. On the basis of existing information on the reactivity worth of the central control rod prior to shutdown and the results of the " Borax " and " Spert " experiments, it is estimated that this rod would need to be withdrawn another 6in to 8in at a rate of approximately 24in per second, to produce a nuclear excursion of the magnitude estimated to have occurred. While these actions and conditions appear credible, they do not appear probable in the light of the evidence yet available.

Additional factors can be considered at this time, which involve the possibility that some changes occurred in the properties of the reactor between December 23, 1960, and January 3, 1961—changes which would decrease the capability of the control system to maintain the reactor shutdown. There is no direct evidence at present that any such changes took place. If loss of cadmium or loss of boron did occur during the shutdown period in question, the shutdown margin of reactivity would have been reduced. With a reduced shutdown margin of reactivity, substantially less withdrawal of the central control rod would have produced criticality. Other conceivable initiating events, though at the present their likelihood appears to be low, include : (*a*) A water-metal, hydrogen explosion, or other chemical reaction, below the reactor core, which would drive the central rod or several of the rods up out of the core, or that would lift the seal plugs and therefore the attached rods by a general pressure increase ; (*b*) Addition of water to a core which had become dry and otherwise changed.

It should be emphasised that the foregoing discussion is limited to possibilities and is not intended to imply any degree of probability. It appears now that the most likely immediate cause involved some unusually large and rapid movement of the central control rod.

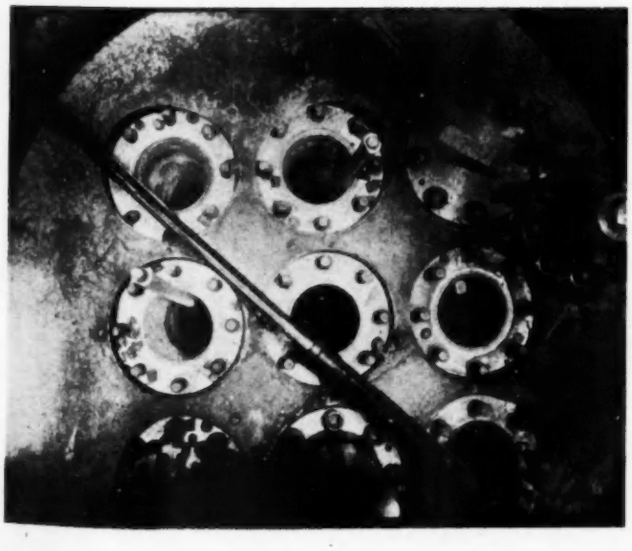


Fig. 7—Downward view of the SL-1 reactor obtained by a remotely actuated movie camera, showing six of the nine nozzles open to the atmosphere

" Packaged " Control for Power Stations

The first standard computer system packaged for "off the shelf " sale to electric power stations has been announced by International General Electric. Because the system can be adapted for use in any power station with little special programming, installation time can be reduced to less than thirty days. Hitherto a computer system required extensive special programming for each installation, which often took months. The new computer is known as the GARDE system and is designed for monitoring, logging and processing of steam plant operational data in power stations. The designation was derived from its functions : Gathers data, Alarms, Reports, Displays and Evaluates.

The GARDE system is designed round the General Electric fully transistorised 312 digital process control computer. It comprises the central computer with a 24,000-word drum memory (expandable to 52,000 words) ; operator's control panel ; electric typewriters for logging data and preparing instructions ; and a built-in programme for routine calculating and checking of turbo-generator operations. During operation at a power station, the new system will gather data to central locations, compute hourly overall heat rate and component efficiencies, constantly check operating values for out-of-limit conditions, automatically prepare logs and automatically record values exceeding pre-set limits.

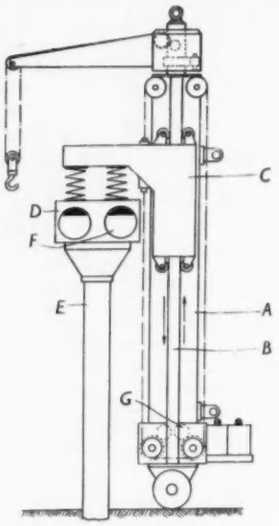
BRITISH PATENT SPECIFICATIONS

The dates printed are those of application and publication on completion. Copies of specifications may be obtained at the Patent Office Sales Branch, Southampton Buildings, Chancery Lane, W.C.2, 3s. 6d. each

CONSTRUCTIONAL EQUIPMENT

872,923. March 31, 1960.—DEVICES FOR RAMMING OR DRIVING PILES, Ludwig Müller, Heinrich-Heine-Strasse 41, Marburg/Lahn, Germany.

This invention relates to a device for driving and drawing pipes or piles, in which alternating dynamic forces are excited in one direction for driving or in the direction opposite for withdrawing a pile by a vibrator. The dolly is a separate structural element associated with actuating gear which is kinetically



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linked through a yoke and spring elements with an unbalanced vibrator and, in conjunction with the actuating gear, acts as a loading or tensioning element. Referring to the drawing the pile driver is shown *A*; the ram or dolly is supported at its foot by a wheel. Associated with the dolly and movable in guides *B* attached thereon are a yoke *C* with a vibrator *D* linked by springs. A ram or tup *E* is rigidly connected to the vibrator. The motors driving the pairs of unbalanced masses *F* are not shown. The gear train *G* situated at the foot of the dolly together with the hoist are intended to take up the static load acting on the tup through the yoke, the yoke springs, and the vibrator in the driving or the hoisting direction.—*July* 12, 1961.

RAILWAY EQUIPMENT

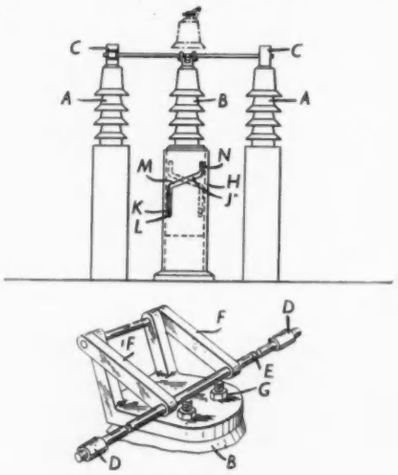
872,917. October 20, 1959.—BRAKING ARRANGEMENTS FOR RAILWAY VEHICLES, British Transport Commision, 222, Marylebone Road, London, N.W.1. (*Inventors: Tom Baldwin and Denis William Peacock*).

An object of the invention is to provide an efficient vacuum braking arrangement, permitting short stopping distances and the avoidance of shocks irrespective of the effects of variable factors, such as train length. The attainment of this object calls for a quick propagation rate for emergency applications and a gradual build-up of braking force. If the rate is too slow, bunching of the train may occur during the first part of the brake application, which may lead to shocks, whereas snatching may occur later, as the braking forces become more nearly equal and the train opens out again. The arrangement comprises in combination a valve which is sensitive to the rate of brake application and permits a large spill back of air into the train pipe upon full brake application, but no spill back upon slow partial brake application. A copy-valve device ensures that the brake-cylinder vacuum copies the vacuum in a reservoir in controlled communication with the train pipe. Such an arrangement, while providing for a controlled rate of build-up of braking force, can be made to discriminate between emergency applications in which the rate of application is, say, greater than 8 inches of mercury per second and partial applications in which the rate is not more than 1½ inches per second. Such a definite difference in rate can be obtained by the use of an appropriate type of driver's brake valve adapted for ensuring that partial application is effected at a controlled rate and to a precisely controlled vacuum reduction. One manner of carrying the invention into effect is described by way of example with reference to drawings.—*July* 12, 1961.

ELECTRICAL ENGINEERING

872,337. March 4, 1959.—ELECTRIC ISOLATING SWITCHES, Switchgear and Equipment Ltd., Southam Road, Banbury, Oxfordshire, and Douglas Arther James Oxley, "Chesterton," Hightown Road, Banbury, Oxfordshire.

This invention relates to electric isolating switches, more especially for high-voltage systems, in which the moving contacts enter the fixed contacts loosely and are then wedged into high-pressure contact with them by twisting. An object of the invention is to provide an improved construction with a minimum number of insulators and with minimum stressing of the insulators. One phase of a high voltage double-break isolator according to the invention is shown in the drawing. The isolator comprises three vertical insulators, namely two fixed insulators *A* and, midway between them, a moving insulator *B*. At the top of each of the fixed insulators is a fixed contact *C* formed to receive a moving contact *D* (lower drawing) which enters it in a horizontal direction at right angles to the line joining the two fixed contacts. The moving contacts are carried by a rod *E* forming a conducting bridge. The moving contacts are of non-circular section and are arranged to enter the fixed contacts loosely by swinging of the bridge about the vertical axis of the central insulator, and thereafter to be wedged firmly into high pressure engagement with the fixed contacts by twisting the bridge and moving contacts so as to bring a greater diametral dimension of each contact into a vertical position. In order to bring about the desired movement the bridge *E* carries a crank *F* which is pivotally connected to a bracket carried at the upper end of the central insulator. The bracket carries a pair of stops *G* arranged to be engaged by the cranks in their lowest position. Starting with the switch in its open position the bridge will have been lowered until it rests on the adjustable stops as shown, with the insulator turned to a position in



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which the bridge is at right angles to the plane joining the fixed insulators. When the closing mechanism is operated it first swings the central insulator *B* about its vertical axis. It is immaterial whether the insulator also moves up or down during this movement provided that when the moving contacts reach the fixed contacts the bridge is at the proper level to enable them to enter. When the central insulator has been turned to the appropriate position in which the moving contacts are correctly (but loosely) positioned in the fixed contacts, the central insulator ceases to turn about a vertical axis and begins or continues to move downwards. The fixed contacts prevent downward movement of the moving contacts and hence of the bridge, and as the bracket on the central insulator moves downwards it carries with it the ends of the cranks and hence turns the bridge about its own axis, thereby producing high-pressure contact between the fixed and moving contacts as already described. The opening movement is the reverse of the closing movement. The lower end of the insulator *B* may be carried on a sliding sleeve *H* mounted to slide up and down telescopically in a fixed cylindrical guide. Inside it the sliding sleeve carries a nut engaging a screwthreaded shaft extending coaxially within it and connected to the driving motor. The fixed guide has in it one or more generally Z-shaped slots *J* to receive rollers *K* carried on pins and projecting into them from the sliding sleeve. Each slot comprises a vertical lower portion *L* curving round into an upwardly inclined portion *M* which in turn curves up into a short vertical upper portion *N*. Accordingly as the sliding sleeve is screwed downwards each roller first travels down the short upper vertical portion of the curve, so that the central insulator moves vertically without rotating. Almost at once the pin reaches the curved part of the groove, and begins to swing the movable insulator *B* about its vertical axis, the curve of the groove being designed to give steady acceleration. As the roller reaches the oppositely curved part of the groove the insulator is again decelerated at a steady rate and stops swinging as the moving contacts come to rest in the fixed contacts. As the pins move down the final longitudinal portion of the slot the stops *G* leave the bridge suspended by the fixed contacts and the cranks twist it to tighten the moving contacts in the fixed contacts.—*July* 5, 1961.

873,026. May 9, 1960.—VARIABLE-FREQUENCY ASYNCHRONOUS GENERATOR SYSTEM, Philippe Caire, 3, Avenue de la Vènerie, Montgeron (Seine et Oise), France.

This invention relates to asynchronous motor supply systems, and its object is to provide a supply system whereby one or more asynchronous motors may be operated under substantially constant power conditions regardless of variations in speed of rotation over a wide range. It is well-known that the speed of rotation of an asynchronous motor may be controlled by modifying its supply frequency. However, since it is generally desired to maintain a constant motor torque, such type of motor speed control will be accompanied by a variation in the power supplied to the motor, which is an undesirable condition. The present invention sets out to provide an improved supply system for asynchronous motors, whereby the speed may be regulated in a simple and efficient manner while maintaining the power supplied to the motors substantially constant. The invention comprises a squirrel-cage asynchronous generator having output windings connected to supply one or more asynchronous motors, means for driving the generator at constant speed, and for supplying excitation power at controllable frequency; and for automatically varying the magnetic flux within the generator substantially in inverse proportion to frequency. In this manner, varying the generator excitation frequency will vary the angular velocity of the rotating field supplied by the generator, and hence the speed of the motors, while maintaining the power output of the generator substantially constant. The specification illustrates a three-phase generator with squirrel-cage rotor forming part of a rotating group driven by a main motor. The ordinary stator windings of the generator are connected to the corresponding windings of the asynchronous motor or motors whose speed is to be controlled. Also on the generator are a set of auxiliary windings connected to an auxiliary three-phase generator driven by a variable-speed motor so as to supply reactive magnetising energy to the generator. The output frequency of this auxiliary alternator, as determined by the speed of its driving motor, in turn determines the frequency of the output from the main generator to the asynchronous motors. In the proposed arrangement the variable-speed motor is controlled on the Ward-Leonard system. It is fed by a generator forming part of the main rotary group, which also includes an exciter for the auxiliary three-phase generator and for the Ward-Leonard generator. Varying the speed of the auxiliary generator by rheostatic control of the Ward-Leonard set excitation in the normal manner makes it possible to vary the frequency of the main alternator supplying the asynchronous motor or motors. Also, varying the excitation of the auxiliary generator by a similar means leads to variation of the voltage in the auxiliary windings of the main generator, and as a result permits regulation of the flux in the main generator. Both controls are effected by rheostats, and if these are linked to one adjustment it is possible by a single control mechanism to vary the speed of the asynchronous motors fed by the system whilst maintaining the power supplied at a constant level.—*July* 19, 1961.